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USNC-IGY ANTARCTIC GLACIOLOGICAL DATA
FIELD WORK 1958

(Wilkes Station Glaciology, 1958)

Report 825-2-Part X
IGY Project No. 4.10
NSF Grant No. Y/4.10/285

John T. Hollin, Caspar Cronk
and Richard Robertson

August 1961

USNC-IGY ANTARCTIC GLACIOLOGICAL DATA

Report Number 2: Field Work 1958

Part X

WILKES STATION GLACIOLOGY, 1958

by

JOHN T. HOLLIN, CASPAR CRONK
and RICHARD ROBERTSON

The Ohio State University
Research Foundation
Columbus 12, Ohio

Project 825, Report No. 2, Part X

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I. INTRODUCTION

This report contains the major part of the glaciological data collected by the 1958 wintering-over party at Wilkes Station. Geological data collected by the party have been published in an earlier report in this series (Robertson, 1959). Glaciological data from the summer of 1958-9, data from the 1958 traverse, and data on glacial geology will be published later. In several cases the measurements reported here are a continuation of those of 1957, and no attempt has been made to duplicate basic information already published in the data report for that year (Cameron et al., 1959). In conformity with IGY procedure, these first reports have been limited to data and to the information necessary for their analysis. The analysis is proceeding as time and funds become available, and will not be published in any one series of reports. A preliminary summary of the glaciological work at Wilkes Station in 1957 and 1958 has been published in the Journal of Glaciology (Hollin and Cameron, 1961) and is recommended as an introduction to this report. Original notebooks, photographs, samples, etc. are stored at the Institute of Polar Studies at The Ohio State University.

The data report for 1957 (referred to hereafter as "the Report for 1957") includes a general topographic description of the Wilkes Station area. Figures 1, 10 and 11 of this volume (Location map, Windmill Islands map and Northern Area map) incorporate additional topographic information recorded by the 1958 party. It was discovered in 1957 that Clark, Bailey, Mitchell and Browning "Islands" are actually peninsulas connected to the ice sheet. In the case of the first three the connection is provided by a "ramp" of relatively stagnant ice, which has an average slope of 5° and rises to a long and sinuous "shear moraine" (see Fig. 10) at the margin of the ice sheet. In this report the "Ramp" always refers to the slope below "the shear moraine", which is approximately 140 m above sea level. The "ice sheet" refers to the main body of the ice above and inland from the shear moraine. The ice sheet can be conveniently divided into three zones: the ablation zone, the superimposed ice zone of accumulation and the firn zone of accumulation. The boundaries between these three zones were found during 1958 to lie at approximately 230 m and 345 m above sea level. Although much of the glaciological work was continuous between 1957 and 1958, the 1957 party concentrated its efforts in the firn zone and the 1958 party in the superimposed ice and ablation zones.

Names used in this volume have been taken from the 1:12,000 U.S. Navy Hydrographic Office charts 6656, 6657, and 6658. The following unofficial names for previously unnamed features became common usage during 1957 and 1958, and are employed throughout the report:

Alexander Moraine		Isolated Moraine
Bayhead Island	(66° 29' S 110° 39' E)	Cone Moraine
Scattered Moraine	(66° 29' S 110° 45' E)	The Corridor

Middle Nunatak	(66° 28' S 110° 43' E)	Ramp Cove
Little Herring Island	(66° 25' S 110° 41' E)	Tide Gage Cove
Grinnell Nunatak		Crescent Moraine
Grinnell Glacier		Mickey Mouse/North Island

These features are shown on Figs. 10 and 11. References in the text to "Pt. 142" etc. are references to spot heights on the 1:12,000 charts. The units of measurement employed are those which were used in the original field work. These were determined by the instruments involved (weasel odometers, altimeters, stadia rods, etc.). Metric equivalents of British units have been provided wherever practicable. References from one section to another section of the report are made by means of the table of contents e.g., astronomical observations are referred to as Section II-B-1. References to the contents of the other reports for 1958 (see above) use the abbreviations "Geology," "Summer," "Traverse," and "Glacial geology."

The members of the 1958 glaciological party were John Hollin (Chief Glaciologist), Caspar Cronk and Richard Robertson. The party arrived at Wilkes Station on 25 January 1958 and left on 6 February 1959. Particularly in the field the party worked as a unit, but in general each man had his own specialty. Hollin concentrated on gravity, englacial and glacial geological observations, Cronk on topographic, movement, meteorological and surface observations, and Robertson on englacial and geological observations. The program profited considerably from the assistance given by every member of the naval and civilian wintering-over party, in particular by Chief R. Griffith, Chief J. Lynsky and Fr. H. Birkenhauer S.J.. After leaving Wilkes Station, and by courtesy of the Australian National Antarctic Research Expedition, Hollin was able to visit Lewis Islet (134° E) and Oates Land (at 157° E). Observations made at those places will be published later. The task of data reduction has been shared by all members of the party but the final draft of this report has been prepared for publication by Hollin. Sections of the report which relate to the work of one man in particular are headed by that man's name. R. Cameron has read and corrected the manuscript. Also acknowledged is the help of V. Schytt, who made available before publication the manuscript of a major part of his results from Maudheim.

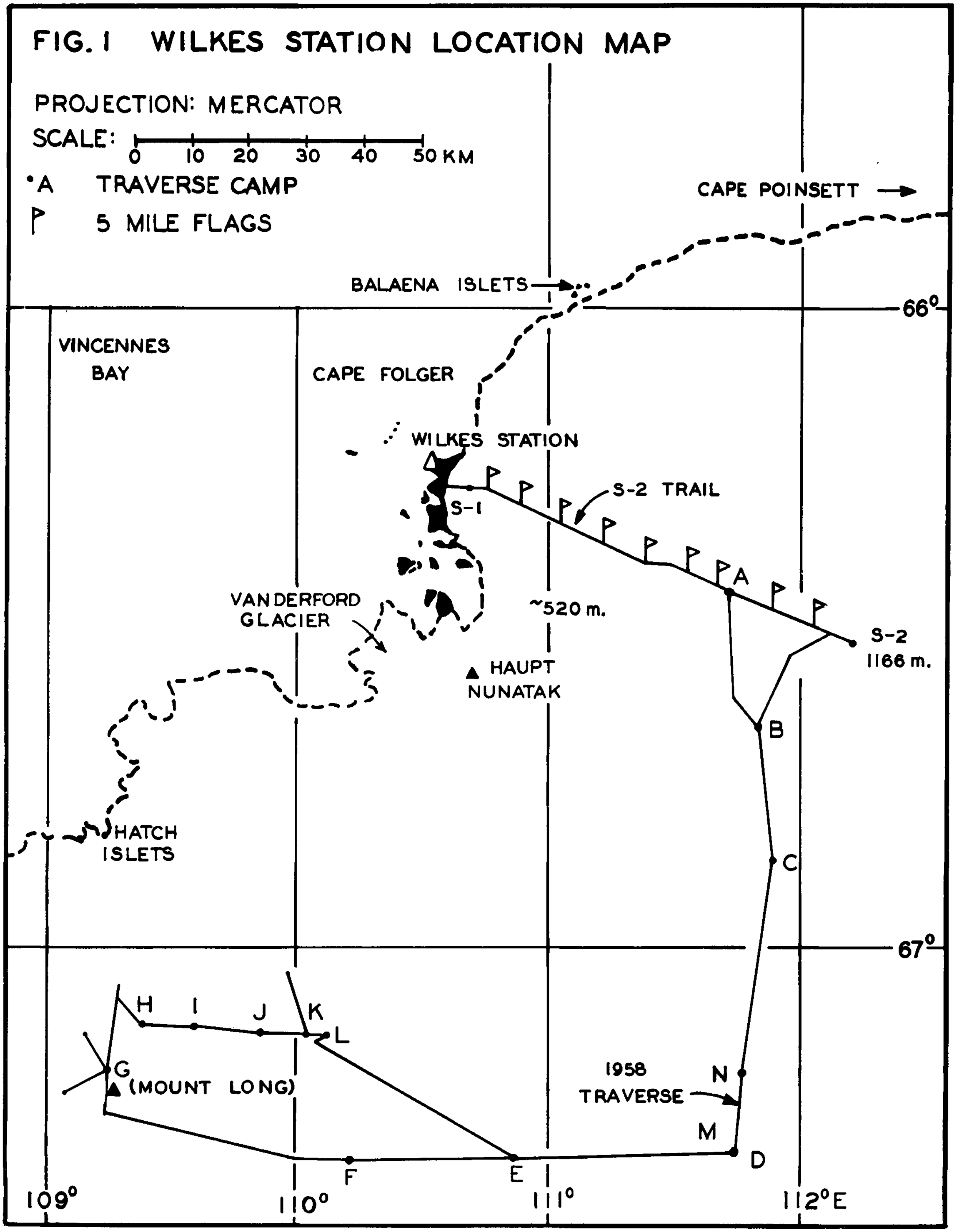


FIG. 1 WILKES STATION LOCATION MAP
PROJECTION: MERCATOR
SCALE:
0 10 20 30 40 50 KM
•A TRAVERSE CAMP
5 MILE FLAGS
CAPE POINSETT
BALAENA ISLETS
66°
VINCENNES BAY
CAPE FOLGER
WILKES STATION
S-2 TRAIL
S-1
A
VANDERFORD GLACIER
~520 m.
S-2
1166 m.
HAUPT NUNATAK
B
HATCH ISLETS
C
67°
H
I
J
K
L
G
(MOUNT LONG)
1958 TRAVERSE
N
M
D
F
E
109°
110°
111°
112°E

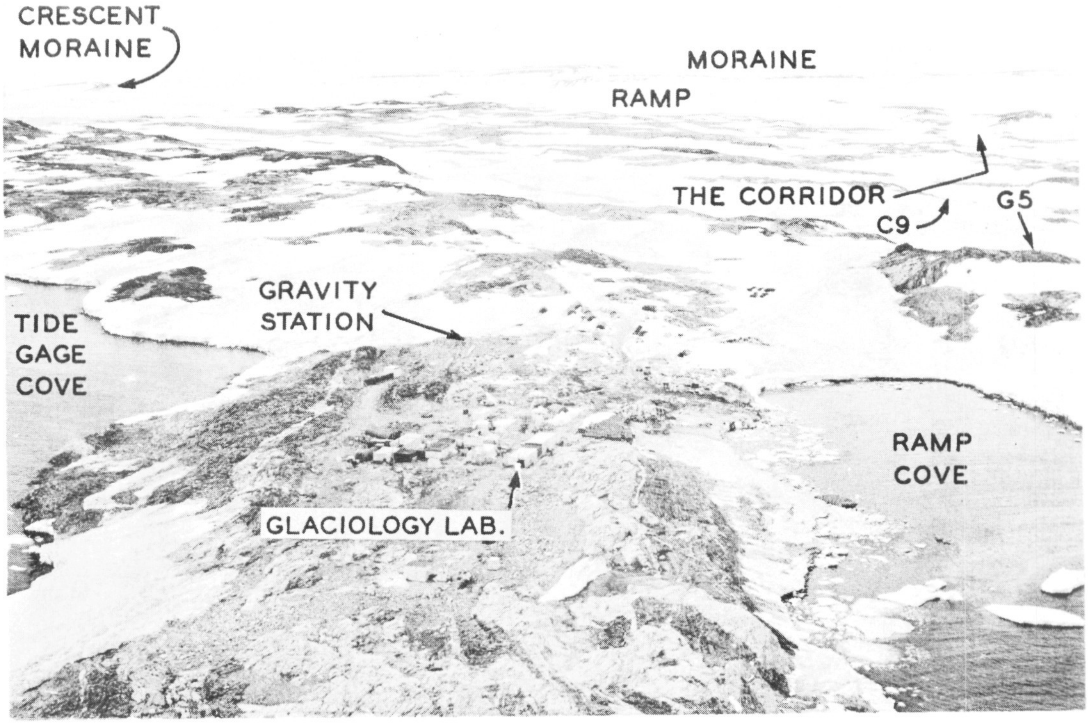


Fig. 2. Wilkes Station from the air, looking ENE.
Official photograph, U. S. Navy

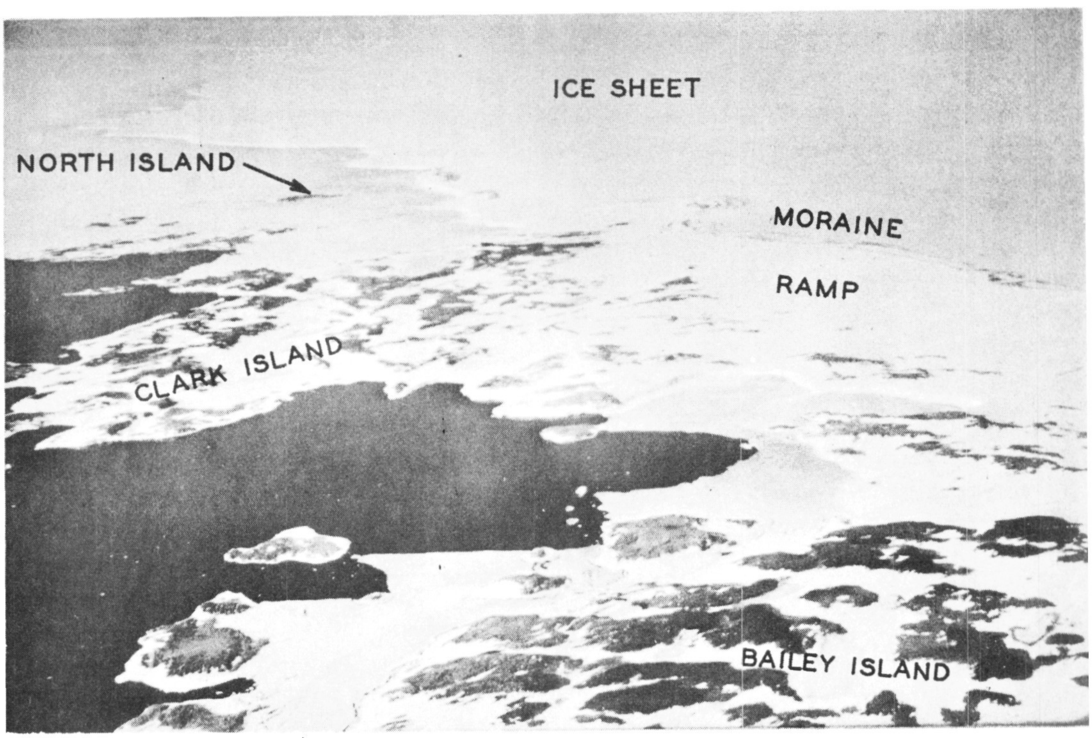


Fig. 3. Clark Island from the air, looking NE.
Photograph by C. Cronk

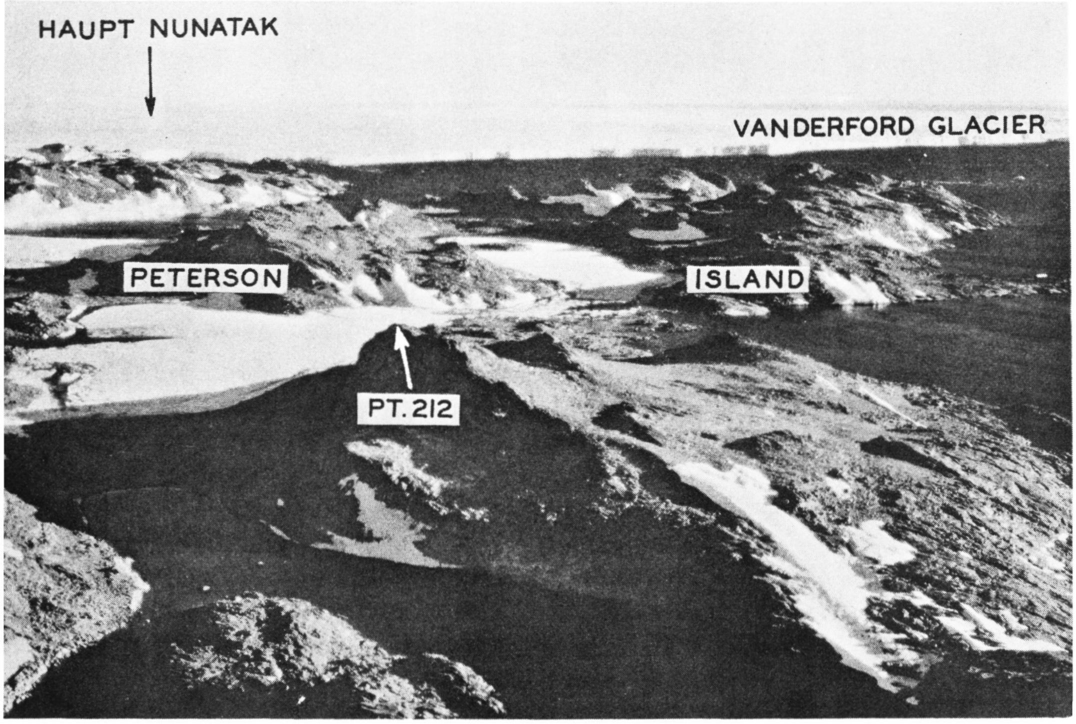


Fig. 4. Peterson Island from the air, looking SSE.
Official photograph, U. S. Navy

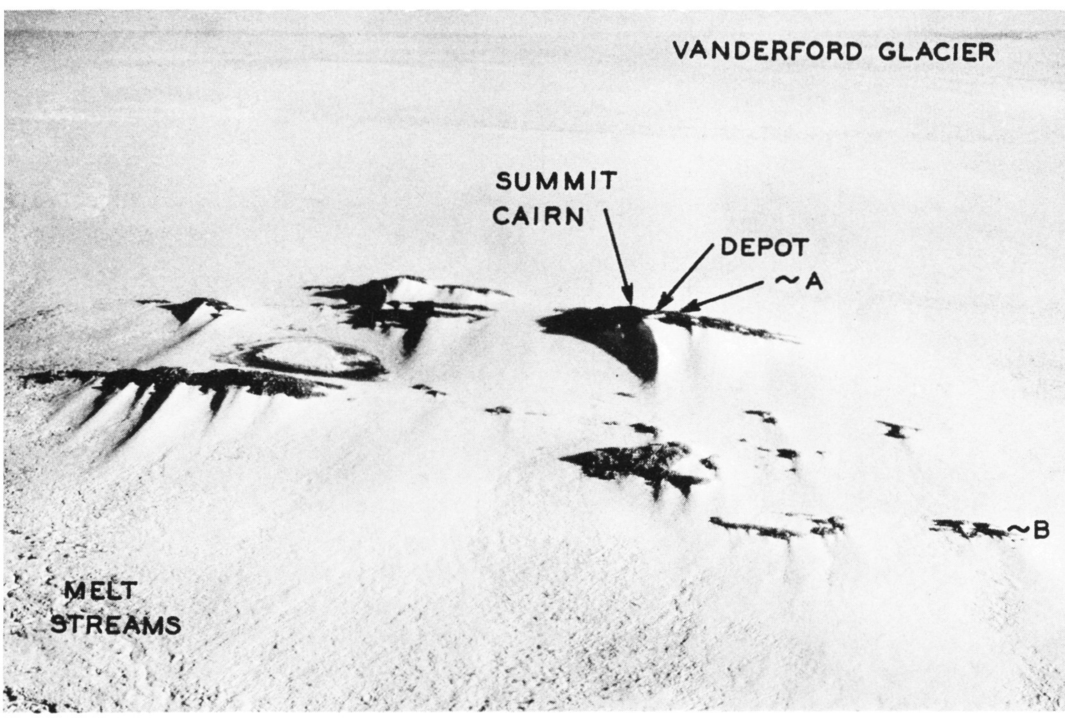


Fig. 5. Haupt Nunatak from the air, looking SSE.
Official photograph, U. S. Navy

II. TOPOGRAPHIC SURVEYS

A. PREVIOUS WORK (Hollin)

The history of exploration in the Wilkes Station area cannot be treated in detail in this report, and no attempt has been made to check the original records of the expeditions involved. However, since the literature on this subject contains some contradictions, the brief discussion below has been prepared.

Lists of place names published by the Soviet IGY Committee suggest that the outcrops here were first discovered by the B.A.N.Z.A.R.E. of 1929-31, but the narratives of that expedition published in The Geographical Journal make this seem unlikely. According to Gazeteer No. 14 of the U.S. Board on Geographic Names ("Geographic Names of Antarctica") the main group of the Windmill Islands was discovered in early 1947 by aircraft of U.S. Navy Operation Highjump. Either just before or just after this discovery land was sighted in this area by an aircraft attached to the British whaling ship Balaena. From the short description in John Grierson's book Air Whaler and from acquaintance with the area it seems likely that the outcrops seen by the British expedition were what are now called the Frazier Islets. However, the name "Balaena Islets" has been given to a group of smaller islands to the northeast (Fig. 1). The Windmill Islands have frequently been referred to, particularly in the Russian literature, as the "Grierson" Islands, Archipelago, Oasis or Hills. During Operation Highjump the islands were photographed from the air, and in 1948 ground control and additional photographs were obtained by U.S. Navy Operation Windmill. The Operations Highjump and Windmill data from this area are incorporated, together with later corrections, in:

(1) U.S. Geological Survey Map E2-66-10 (Antarctica Reconnaisance, Preliminary Base, Australian Quadrant) and in

(2) U.S. Navy Hydrographic Office charts H.O. 6656, 6657, 6658 (1:12,000) and H. O. 6659 (1:50,000).

The chief errors in (1) above are that:

(a) Clark Island, Bailey Island, Mitchell Island and Browning Island are shown as islands, but are in fact peninsulas joined to the mainland.

(b) Haupt Nunatak is shown as 600 ft. high but is in fact only 279.5 ft. high.

(c) Mount Long (6500 ft.) and Davis Peak (3100 ft., name taken from the National Geographic Society map of Antarctica) do not exist.

(d) The heights on the interior contours are too great by a factor of approximately 2.

The charts (2) above were used by the glaciological parties of both 1957 and 1958 and although the charts do not cover the whole of the Windmill Islands, what they do show is apparently accurate. Heights determined by the 1958 party checked within a few feet with chart heights.

In early 1956 the Windmill Islands were visited by Australian (January), Russian (February) and American (March) ships. All three parties visited the Balaena Islets. An Australian aircraft photographed the area, and ground parties worked throughout the islands. Australian maps based on this 1956 work use place names which are different from the American. In October 1956 a Russian party landed by air on the ice sheet inland from the islands, and worked in the area for a few weeks. Air photographs in the Wilkes Station region were taken by Russian parties in 1956 and 1958. Russian maps of this area numbered Q-49-77, 78 and Q-49-89, 90 have been published on a scale of 1:100,0000. These maps are currently the best available for the Frazier Islets, Chappel Islets, the area north of Clark Island and the area southeast of Browning Island.

Sustained observations in the Windmill Islands area were begun in February 1957, following the establishment of the US IGY base "Wilkes Station," sometimes called "Knox Base." During 1957 a triangulation of the area north of Wilkes Station was completed by the U.S. party. The details of this triangulation are held by the U.S. Geological Survey. Points from this 1957 survey have the prefix "W"; e.g., W10 on the Northern Area Map (Fig. 11) has been plotted from the 1957 data. In January 1958 oblique photographs of much of this area were taken by J. Molholm (glaciologist) from a U.S. Navy helicopter. The survey work undertaken after that date is described below.

In the course of all these visits to the Windmill Islands numerous marine soundings have been made by American, Australian, and Russian ships. No attempt has been made to compile these, but in the report for 1957 Cameron has used soundings taken in early 1958 to chart a submarine trench northwest of the Vanderford Glacier.

B. SURVEYS IN 1958

1. Astronomical Observations

The position of Wilkes Station was determined during the winter of 1958 by S. Borrello (geophysicist) and Lt. (jg.) Eyres, USN, using a Wild T-2 theodolite and ship's chronometer. Observations were made in a shelter a short distance due east of B2 (Fig. 11). The position of B2 reported by Borrello (private communication) is:

Lat.	66°	15'	24"	±	03"	S.
Long.	110°	31'	31"	±	03"	E.

This longitude figure is 2" greater than one reported by Eyres (private communication). The original records of this observation are held by the U.S. Geological Survey.

The position of S-2 was determined by the glaciological party of 1957 using a Dietzgen transit. The following result was obtained:

Lat.	66°	30.7'	S.
Long.	112°	12.8'	E.

2. Triangulation of the Northern part of the Windmill Islands

This was the major survey project of 1958, and was organized by Lt. (jg.) Eyres, USN, and Dr. W. Tressler. Base lines were laid out on Clark Island and on the sea ice near Mitchell Island, and angles measured with a Wild T-2 theodolite. The original data from this triangulation are held by the U.S. Geological Survey. Points in this survey have the prefix "G". The positions of those on Clark and Bailey Islands have been computed by Lt. Eyres and plotted on the Northern Area map (Fig. 11) of this report. Note in the original data a discrepancy in the 1957 and 1958 distances between G4 and G5 (925 and 927.1 ft.).

3. Angles from Holl Island

Angles from "Astro" and Pt. 311 on Holl Island were recorded in December 1958 by S. Borrello (geophysicist), using a Wild T-2 theodolite. Sights were made to the G series of points in Survey B-2, and to points on Peterson and Browning Islands which included the North and South bases in Survey B-4. At Astro (see chart H.O. 6657) a rod was driven into the rock at its highest point, and the theodolite was positioned over the drill hole. Only after the angles had been taken was the original Operation Windmill Astro point discovered; a small metal disc in a crack some 30 feet northeast of the 1958 point. These measurements from Astro and Pt. 311 will be forwarded to the U.S. Geological Survey.

4. Triangulation of Southern Area and Haupt Nunatak (Cronk)

This survey was carried out in December 1958, using an Invar tape and Wild T-2 theodolite. A baseline BC, 100 m long, was laid out on the sea ice north of Browning Island. From this original short baseline a longer one, BD, was triangulated with as much accuracy as possible. Triangle BCD has a closure error of two seconds and the length of BD is 1090.86 meters.

From point B angles were measured between the following points:

1. North Base "N" (Pt. 228, N. Browning Island)
2. Point D on the baseline
3. South Base on Back (or Sack) Rock

The distances and angles between these points are held at The Ohio State University. In 1958 they were plotted graphically and appeared to fit well with a check triangulation of point 5 from Clark Island. In 1960 the position of 5 by subtense and triangulation was worked out in coordinates. These showed that the subtended poisition of 5 was misplaced 80 meters northeast of the triangulated position. It has proved impossible to locate the source of this error precisely. The triangulated position of 5 is at the correct distance and direction from the triangulated position of LB in Movement survey III-F, so that the error must be in the subtense survey. The most likely sources of error in the subtense survey would be deflections of the bar by wind, unusual refraction, or simply an incorrect theodolite reading.

To plot the subtense survey on the Northern Area map (Fig. 11) the position of point 5 has been adjusted to the triangulated position and the positions of all the intermediate points adjusted accordingly. The result is a very close fit to air photographic data and provides adequate horizontal control for the gravity survey. Above point 5 the convexity of the ice sheet precluded any convenient check of the subtense survey by triangulation from below. The only evidence for tis accuracy is provided by comparing the subtended height between B14 and S-1 (121 m) with the same height measured by altimetry (122 m). The horizontal positions of all the points in the subtense survey have been plotted on the Northern Area map (Fig. 11). The elevations of these points are included in the table of elevations (II-C-2) at the end of this section.

7. Plane-table and levelling surveys of Clark Island

These surveys, which cover the northwestern half of Clark Island, were organized in the austral summer of 1958-9 by S. Borrello (geophysicist) and Lt. (jg) Eyres, USN. Their original plane-table map is held by the Hydrographic Office at Washington D.C., and their levelling data by the U.S. Geological Survey. Some of the horizontal data has been incorporated in the Northern Area map (Fig. 11) and some of the vertical data in the table of elevations (II-C-2) at the end of this section.

8. Plane-table survey of North Island (Mickey Mouse Island)

This was completed by R. Robertson (glaciologist) and S. Borre[illegible] (geophysicist) for geological purposes. The original is held at The Ohi[illegible] State University.

9. Ramp profile

For most of its length between northern Clark Island and southern Mitchell Island, the Ramp appeared to be slightly concave. An actual survey of the Ramp at its widest point on Clark Island was made by J. Hollin and R. Robertson on 22 November 1958. The line of

The following final heights have been calculated:

North Base "N" 233.9 ft. (71 m) (compare chart height of 228.0 (70 m))
South Base "S" 320.6 ft. (98 m)
Haupt Nunatak (vertical angles from N) 276.6 ft. (84 m)
Haupt Nunatak (vertical angles from S) 279.5 ft. (85 m)

For Haupt Nunatak the latter figure is probably more reliable, since the sight from N passed just above an intervening ridge which, in the prevailing conditions of low air temperatures and warm rock surfaces, would tend to produce irregular refraction effects.

The point on Haupt Nunatak observed in this survey was the cairn on the highest point of the most prominent member of what is actually a group of small outcrops (Fig. 5). The height of 279.5 ft. (85 m) above may be compared with a figure of 304 ± 50 ft. (93 ± 15 m) obtained by three uncorrected altimeter readings and of 81 m (265.8 ft.) shown on the Russian maps mentioned previously. The help of Chief R. W. Churchill, USN, in the practical work of this survey is gratefully acknowledged.

5. Triangulation of the shear moraine

Angles (to the nearest 15 minutes) from the "G" points of Survey II-B-3 to four points on the main shear moraine were measured by C. Cronk during 1958. These points have been plotted on the Northern Area map (Fig. 11).

6. Subtense survey in the Northern Area (Cronk)

This survey, completed during the austral autumn of early 1958, was designed to fix the position and elevation of points in the gravity survey. Angles were measured with Kern DKM-2 theodolite No. 54717. A subtense bar was constructed of angle iron, cut so that it had a length of five meters at outside temperatures (approximately -7°C). The bar was equipped with a small spirit level and was mounted on a plane-table tripod. A sighting device enabled the bar to be oriented at right angles to the line of survey.

The subtense survey began at B2 (at Base) and finished at Gravity Station B3, 8 km inland from Newcomb Bay. (Note that there are two points called B2: the one at Base and a gravity station on the ice sheet.) The following points, all of which are on or close to the S-2 trail and are marked on the Northern Area map (Fig. 11), were included in this survey: 1(B2), 2, 09, 3, C8, 4, C7, C6 (a flag 1.72 m above the gravity station a few meters away), 5 (red board, red flag, and small cairn just below a moraine peak; note for the future that both 5 and point LB to the northeast of 5 should be more clearly marked), Grinnell Nunatak (1957 marker - see Movement survey III-G), C5, C4, C3, C2, B14, C1, A1, B13, B12, 406 (accumulation stake), B11, B10, B9 (S-1), B8, B7, B6, F2B, and B3.

The distances and angles between these points are held at The Ohio State University. In 1958 they were plotted graphically and appeared to fit well with a check triangulation of point 5 from Clark Island. In 1960 the position of 5 by subtense and triangulation was worked out in coordinates. These showed that the subtended poisition of 5 was misplaced 80 meters northeast of the triangulated position. It has proved impossible to locate the source of this error precisely. The triangulated position of 5 is at the correct distance and direction from the triangulated position of LB in Movement survey III-F, so that the error must be in the subtense survey. The most likely sources of error in the subtense survey would be deflections of the bar by wind, unusual refraction, or simply an incorrect theodolite reading.

To plot the subtense survey on the Northern Area map (Fig. 11) the position of point 5 has been adjusted to the triangulated position and the positions of all the intermediate points adjusted accordingly. The result is a very close fit to air photographic data and provides adequate horizontal control for the gravity survey. Above point 5 the convexity of the ice sheet precluded any convenient check of the subtense survey by triangulation from below. The only evidence for tis accuracy is provided by comparing the subtended height between B14 and S-1 (121 m) with the same height measured by altimetry (122 m). The horizontal positions of all the points in the subtense survey have been plotted on the Northern Area map (Fig. 11). The elevations of these points are included in the table of elevations (II-C-2) at the end of this section.

7. Plane-table and levelling surveys of Clark Island

These surveys, which cover the northwestern half of Clark Island, were organized in the austral summer of 1958-9 by S. Borrello (geophysicist) and Lt. (jg) Eyres, USN. Their original plane-table map is held by the Hydrographic Office at Washington D.C., and their levelling data by the U.S. Geological Survey. Some of the horizontal data has been incorporated in the Northern Area map (Fig. 11) and some of the vertical data in the table of elevations (II-C-2) at the end of this section.

8. Plane-table survey of North Island (Mickey Mouse Island)

This was completed by R. Robertson (glaciologist) and S. Borrell. (geophysicist) for geological purposes. The original is held at The Ohio State University.

9. Ramp profile

For most of its length between northern Clark Island and southern Mitchell Island, the Ramp appeared to be slightly concave. An actual survey of the Ramp at its widest point on Clark Island was made by J. Hollin and R. Robertson on 22 November 1958. The line of this profile is shown on the Northern Area map (Fig. 11) The base point of the survey was established a few meters to the south of a prominent boulder at the lower limit of the Ramp, where the snow surface was approximately horizontal. From this point transit readings were taken on a stadia rod held (a) at Point C7 (in order to connect this survey to the main survey network) and (b) at 16 points on the profile. Halfway through the survey the transit was moved up to Point 11, so that the stadia rod could be read more easily. As far as possible the profile followed the line of greatest slope. Bearings (transit, true - see Section II-B-13) from the base were: to C7, 150°; line of profile, 129°.

The following heights and distances have been calculated:

Point	Ht. above base point (meters)	Distance (meters)
C7	7.2	216.6
1	1.1	61.0
2	3.4	120.8
3	6.4	193.3
4	10.4	267.2
5	15.6	348.6
6	21.2	432.6
7	27.9	522.8
8	33.3	570.1
9	43.7	695.8
10	54.7	835.6
11	61.4	892.7
12	71.5	993.9
13	83.2	1096.6
14	89.7	1141.2
15	96.2	1180.9
16	102.2	1209.9

This information is plotted graphically in Fig. 7. Also plotted is the amount of 1958 snow (sounded with a SIPRE 1-inch drill) measured at each point. On the ground the line of the profile appeared generally concave, but flat or slightly convex above Point 11. Bare ice patches were plentiful between points 6 and 7 and occurred as far up the slope as Point 9. Above Point 11 the snow surface showed 25-30 cm of relief and was rougher than below.

Note that the profile of the Ramp is controlled probably by three factors:

a. The mechanical properties of the ice sheet,
b. Degradation and aggradation by summer melt streams,
c. Aggradation by blown snow deposited in the lee of the shear moraine.

A further study of these factors might lead to some useful conclusions concerning the age of the Ramp. It is clear from the survey that the Ramp has existed long enough for (b) and (c) above to change the convex shape which (a) would produce.

10. The S-2 trail

The S-2 trail was surveyed on 15, 16, and 17 April 1958, by J. Hollin in one weasel and R. Robertson in another. Mileages were recorded by weasel odometer, horizontal angles by transit readings to the nearest 15-minutes, and heights by altimetry. A leapfrog system was used, and contact between vehicles maintained by hand signals and walkie-talkie radio. As each vehicle moved forward to a new station it would pass the other vehicle, so that frequent checks could be made of odometer and altimeter readings. At each station the following were recorded: the time and odometer and altimeter readings on arrival, the altimeter reading and air and altimeter temperatures 10-minutes after arrival, and the clockwise angle between the previous and next stations. To obtain this angle Surveyor A had to sight on Surveyor B's tripod, then allow his (A's) instrument to stand until Surveyor B had moved forward past A, chosen the next survey point and re-erected his (B's) tripod. Surveyor A could then swing his instrument clockwise to complete his measurement. Points chosen for stations were either important landmarks (e.g., the Red Flags inserted every five miles by the 1957 party and used as accumulation stakes) or points at the visibility limit imposed by the convexity of the ice sheet. Note that the trail was marked chiefly by empty fuel barrels approximately 1/2-kilometer apart. These tend to drift over in one or two years.

The altimetric part of this survey is discussed later. The results of the directional part are listed below.

Station No.	Description and nomenclature in other surveys	Clockwise angle between previous station and next station		Total trail distance from Wilkes Station (miles)	(km)
S1	Outside meteorological office				
S2	Crest of bayhead ridge (west of subtense point 3)				
S3	Southern gap (5 ft. elevation above B14)				
S4					
S5	S-1, B9			5.1	8.2
S6	B7	177°	15'	5.9	9.5
S7	B6	200	20	6.35	10.2
S8	2 barrels above S7	195	35	7.15	11.5
S9	Next barrel, 150 m below BF2	178	20	7.8	12.5
S10	Next barrel	178	02	8.55	13.8
S11		178	15	9.05	14.6

Station No.	Description and nomenclature in other surveys	Clockwise angle between previous station and next station		Total trail distance from Wilkes Station (miles)	(km)
S12	Crushed barrel	180°	11'	9.5	15.3
S13		177	15	10.0	16.1
S14	"Mile 10", Red Flag 8, A3	177	19	10.6	17.0
S15		172	10	11.0	17.7
S16		192	40	11.7	18.8
S17		181	25	12.2	19.6
S18		178	15	12.85	20.7
S19		171	20	13.4	21.6
S20	Tall black post	183	08	14.65	23.6
S21	"Mile 15", Red Flag 7, A4	175	00	15.75	25.3
S22		189	59	16.75	26.9
S23		183	50	17.5	28.2
S24		172	55	18.95	30.5
S25		183	55	19.95	32.0
S26	"Mile 20", Red Flag 6, A5	177	25	20.8	33.5
S27		189	25	21.65	34.8
S28		170	03	22.6	36.4
S29		167	15	23.2	37.4
S30	"Mile 25", Red Flag 5, A6	167	00	25.75	41.4
S31	Small red flag on high bamboo	200	50	29.2	46.9
S32	"Mile 30", Red Flag 4, A7	186	11	30.75	49.5
S33	Angle here may be a few degrees in error	180	40	31.9	51.1
S34		176	13	34.7	55.4
S35	"Mile 35", Red Flag 3, A8	176	10	35.8	57.6
S36		177	53	38.25	61.5
S37		179	35	40.1	64.5
S38	"Mile 40", Red Flag 2, A9	177	10	40.8	65.6
S39	A relative crest. S-2 comes into view	185	05	43.5	70.0
S40	"Mile 45", Red Flag 1	180	12	45.75	73.6
S41	S-2			50.95	82.0

The above angles and distances have been plotted in the first place on a scale of 1: 50,000, starting from the positions of S5 (B9), S6 (B7), and S7 (B6) determined in Section II-B-6. The position of S-2, so plotted, is 3.9 km south of its astronomically determined position. For the purpose of plotting on the Wilkes Station Location map (Fig. 1) the survey has been adjusted merely by pivoting the whole plot counter-clockwise on B14. This provides a rough correction for the direction of the survey but leaves a discrepancy in distance of 500 m. In view of the limitations of the weasel odometer and of the astronomical method this discrepancy is small. Since the scale of Fig. 1 is relatively small the trail has been divided for plotting purposes into five sections:

Section	Bearing (true)	Maximum distance any one station in the section is offset from a straight line
S3-F2B	96°	150 m
F2B-S30	114	450 m
S30-S31	88	-
S31-S34	114	100 m
S34-S-2	106	200 m

As old markers are replaced and new ones inserted the trail tends to become straighter. Originally there was a 45° corner between S33 and S34 but this has since been eliminated.

Note that the trail above does not necessarily run at right angles to the contours. Early in 1957, the glaciological party of that year travelled 40 km due east onto the ice sheet from Wilkes Station (the line of this journey was called the Sullivan trail) and noticed occasional high ground to the south. On the S-2 trail the 1958 party frequently noticed high ground to the north. From these and other observations it seems that the contours over much of the trail have a north-south trend; i.e., that the most rapid rise is to the east. The results of Movement survey III-H show that the greatest slope at S-2 itself is in an approximately east-west direction. More information on surface slopes is included in Section IV.

11. Traverse positions and elevations

These will be included in the report on the traverse. The line of the traverse and the positions of camps are marked on the Wilkes Station Location map (Fig. 1). Note that, as stated earlier, "Mount Long" and "Davis Peak" do not appear to exist.

12. Magnetic bearings

"Transit" or "prismatic" bearings were taken with either a transit compass (estimated accuracy of observations ± 1/4°) or a British Army Prismatic compass (estimated accuracy of observation ± 4°). Because of the considerable fluctuations in the magnetic variation (normally 85° W at Wilkes Station) in this area, bearings have been corrected to true bearings using Wilkes Station magnetograms. These bearings are described in the report as "true". Bearings not yet corrected, and bearings taken in early 1959 (magnetograms not yet available), are reported as "magnetic" and may include errors of up to 5° in addition to the possible observation errors of 1/4° or 4° described above.

13. Plans of Wilkes Station (Fig. 8) and S-2 (Fig. 9)

These plans were prepared in 1958 by Lt. (jg) Eyres, USN, and are reproduced here for reference. At S-2, at the current rate of snow accumulation, the meteorological mast (triangular cross section) southeast of the Jamesway and the radio mast (rectangular cross section) north of the Jamesway should remain above the surface for approximately twenty years.

14. Mean sea level

From 5 March to 19 April, and 15 December 1958 to 2 February 1959, a tide gauge was operated at Wilkes Station by W. Tressler (hydrographer), R. Robertson (glaciologist), and Lt. (jg) Eyres, USN. A report on this project by Dr. W. Tressler has been summarized and included in IGY Bulletin No. 32 (Tressler, 1960a). Mean sea level on a tide staff with an arbitrary zero was 4.59 ft. in the austral autumn and 4.13 ft. in the austral summer. For the purpose of this report, mean sea level has been taken as 4.36 ft. on the staff. The graduations on the tide staff were linked to survey points nearby by Lt. Eyres, whose original levelling data are in field note books held by the U. S. Geological Survey. In the table of elevations in this section 4.36 ft. on the staff has been taken as an elevation of zero.

15. Determination of elevations

Elevations on Clark Island and the S-2 trail were determined in three ways:

a. Elevations below S-1 (262 m) by the subtense method.

b. The elevation of S-2 (1166 m) meteorologically.

c. Elevations between S-1 and S-2 by simple altimetry.

a. Elevations to S-1

These elevations have been obtained primarily from Section II-B-6, with checks supplied by triangulation and by the vertical part of Movement survey III-F. The results of these checks are listed below:

(i) Grinnell Nunatak	Feet	Meters
A. Ht. of B2 by levelling	45.48	13.86
+ interval B2 - Grinnell Nunatak by subtense	111.13	33.87
	156.61	47.73

		Feet	Meters
B.	Ht. of G5 by triangulation	115.05	35.07
	+ interval G5 - Grinnell Nunatak by triangulation	39.70	12.10
		154.75	47.17

(ii) Subtense point 5

		Feet	Meters
A.	Ht. of B2 by levelling	45.48	13.86
	+ interval B2 - 5 by subtense	406.88	124.02
		452.36	137.87
B.	Ht. of Grinnell Nunatak by triangulation	154.75	47.17
	+ interval Grinnell Nunatak - 5 by subtense	295.37	90.03
		450.12	137.20
C.	Ht. of G5 by triangulation	115.05	35.07
	+ interval G5 - 5 by triangulation	338.70	103.24
		453.75	138.30

(iii) Interval Subtense point 5 - A1

		Feet	Meters
A.	By subtense	111.32	33.93
B.	By levelling (Movement Survey III-F)	110.215	33.59
	- estimated (not measured) ht. of 5 above "Y"	4.00	1.22
		106.215	32.37

(iv) A1

		Feet	Meters
A.	Average ht. of 5	452.08	137.79
	+ interval 5 - A1 by subtense	111.32	33.93
		563.40	171.72
B.	Average ht. of 5	452.08	137.79
	+ interval Y - A1 by levelling (Movement Survey III-F)	110.215	33.59
	- estimated (not measured ht. of 5 above "Y"	4.00	1.22
		558.294	170.17
C.	Ht. of G5 by triangulation	115.05	35.07
	+ interval G5 - ridge above Lower Base (Movement Survey III-F) by triangulation	350.20	106.74
	- estimated (not measured) ht. of ridge above Lower Base	2.5	0.76
	+ interval Lower Base - A1 by levelling (Movement Survey III-F)	89.15	27.17
		551.90	168.22

Checks of the original data have failed to reveal the source of the discrepancy in these value for A1. Most probably three errors have been made: (1) The subtense survey (Topographic survey II-B-6), which has an error in distance of +80 meters in 4380, probably has a proportional error in height of 7 ft. (2 m) in 406 (124). (2) The triangulation of G5 - 5 probably includes an error of observation or refraction. (3) The subtended interval between 5 and A1 is obviously incorrect when compared with the very definitely correct levelled interval. Corrections based on these errors would reduce the height of Point 5 to 445 ft. (136 m) and of A1 to 551 ft. (168 m). However, in the absence of any proof of the errors above, the only heights which can justifiably be accepted are: for Point 5 and average of A, B, and C; i.e., 452.08 (137.79), and for A1 an average of A, B, and C; i.e., 557.86 (170.04). Both values may be in error by as much as 10 ft. (3 m) though this is unlikely. In spite of the low order of accuracy of these determinations, they are nevertheless adequate for their primary purpose of providing control for the Gravity survey. Below A1, intermediate heights obtained from the subtense survey have been adjusted to the above two values. Above A1, as far as S-1, elevation differences from the subtense survey have been added onto the above value for A1. The only check on these is provided by altimetry, which for the interval between B14 and S-1 showed a height of 410 ft. (122 m), compared with the subtense figure of 397 ft. (121 m).

b. The elevation of S-2 (Hollin)

The problem of elevation control over ice sheets has been discussed recently by several authors (Hamilton _et al_., 1957; Robin, 1958; Ostenso and Bentley, 1959; Theil and Behrendt, 1959; Kangos, 1959; Gusev, 1959; Gilbert _et al_., 1960). In general, these authors dismiss the method of levelling and discuss those methods dependent on atmospheric pressure. Gusev, however, describes an inertial method which used airborne accelerometers in conjunction with a radio altimeter.

At Wilkes Station, above S-1, in order to save time, pressure methods of determining elevation were employed. The pressure-altitude relationship used has been taken from Smithsonian Meteorological Tables (Fifth Revised Edition, First Reprint, 1939) 51-55, and is based on the hypsometric formula of Laplace. Table 51, the basis of the calculations, shows the pressure-altitude relationship in a column of dry air at 50°F, subject to gravity at sea level at 90° latitude. Tables 52-55 include correction factors for departures from this arbitrary humidity, temperature and gravity.

The pressure method has been applied in two parts. Firstly, the height interval between Base and S-2 has been calculated using the above tables, with additional corrections for the pressure gradient between the two points and for horizontal variations in the vertical structure of the air. Secondly, the heights of intermediate points between S-o and S-2 have been calculated by simple altimetry (Table 51, above, plus the temperature correction only). These intermediate heights have been adjusted to the more accurately determined heights of S-1 and S-2.

To avoid the effect of pressure changes with time, readings had to be taken simultaneously. In the case of the first part, this was facilitated by the fact that readings taken at any time at S-2 (or at any other point) could be matched against the continuous readings (corrected barograph) taken by U. S. Navy aerologists at Base. In the case of the second part, simultaneous readings for altimetry on the trail were secured by standard "leapfrog" methods.

Pressures at Base were taken from a barograph trace which was checked every six hours against a mercury barometer corrected for temperature and gravity. Pressures away from Base were measured with two Wallace and Tiernan FA 181 altimeters, Nos. 9357B and 15147B, on which readings could be estimated to the nearest five feet. The scales of these altimeters are calibrated using Smithsonian Meteorological Table 51 (zero equal to -1000 ft.). Copies of Table 51 are included in an instruction manual. Temperature and humidity corrections based on Tables 52 and 54 are supplied in nomogram form with both the instruments and their instruction manuals. With the aid of Table 51 and an adjustment screw provided, these altimeters could be set to agree with the mercury barometer at Base and could be used thereafter as either barometers or altimeters. Both instruments performed well and, for example, checked within 5 ft. (.005") of the mercury barometer on their return from the 1958 traverse, which had involved 61 days of excessive shaking and vibration in temperatures down to -48°F and pressures down to 25 inches of mercury.

The checks above were, however, made at room temperature, whereas the instruments were used in the field at temperatures down to -48°F. Presumably as a result of <u>instrument</u> (not <u>air</u>) temperature effects, readings of the two instruments out in the field differed usually by 5 or 10 ft. and at the lowest temperatures by as much as 20 ft. (in one case 30 ft.).

For each instrument a temperature correction chart was provided by the manufacturers. As an additional check after the return of the expedition both instruments were calibrated by the manufacturers at 500 ft. height intervals between 0 and 7000 ft. and at 15°F intervals between 0 and 75°F. The results of this calibration showed little correlation with the original temperature correction chart. On the positive side, however, they did show that the instrument temperature corrections were in fact small, exceeding 10 ft. in only a few cases. In view of the above, no attempt has been made to apply a temperature correction to the altimeter readings (except for those taken on the traverse). Instead, the readings have merely been scaled to the average reading of the two instruments, obtained whenever they were observed at the same place and time. These scaled readings include, therefore, instrument errors which may reach 10 ft. (3 m) but are likely to be much less.

The height interval between Base and S-2 would be most accurately calculated by computations based on a large number of pressure readings over a long period of time. Such readings were made during 1957, but are unsuitable for this calculation since the instruments available at S-2 during that year were of limited accuracy. The only pressure readings at S-2 during 1958 were taken with the Wallace and Tiernan altimeters described above. Only two of these coincide closely enough with upper air soundings at Base to be useful in the calculation below. These are sufficient to determine the height of S-2 within ± 50 ft. (15 m), which is adequate for all present purposes. However, arrangements have been made for more pressure measurements to be made at S-2, and if the procedure below can be repeated for several tens of readings it should be possible to obtain an accuracy of ± 20 ft. (6 m). In any event pressure methods rather than levelling do seem to afford the best method of elevation control in the interior here, since during summer at least the considerable inversion which distorts the standard atmosphere above stations still further inland is absent in this relatively coastal situation.

Calculations of the height of S-2 based on pressure readings on 14 and 16 November 1958 are shown below. Note the following:

Lines 7 and 9. Temperatures and humidities interpolated from upper air soundings at 0000 and 1200 Greenwich.

Line 10. The "weight of mercury" component of Table 53 has been omitted as unnecessary for aneroid barometers.

Line 12. Correction for pressure gradient calculated by J. Kangos, U. S. Weather Bureau, from upper air sounding wind data and from surface pressure charts. Upper air winds have been preferred to surface winds for this purpose because of (a) the relatively short distance (80 km) of S-2 from Wilkes Station and (b) the tendency of the surface winds in an inversion to be controlled by topography rather than by the general pressure gradient.

Lines 13 and 14. To this point the calculations have been made on the assumption that the vertical structure of the atmosphere (in particular its temperature and humidity) is the same above the ice sheet as above Wilkes Station, where the upper air soundings were made. In fact, horizontal differences due primarily to inversion may sometimes be appreciable. Gilbert, et al., (1960) have considered the affect of these differences and of wind speeds ("Bernouilli correction") in calculating the height of Charcot station. In one of their winter calculations these items involved a total correction of 31 meters, so that their consideration is important. However, in the case of S-2 on 14 and 16 November 1958, the correction for these factors is probably negligible. On 14 November the surface temperature at S-2 measured by the glaciological party was the same as that at the same pressure above Wilkes Station. The same was true on 16 November; in addition surface temperatures on that day, recorded by the glaciological party at 5 mile (8 km) intervals on the trail to Wilkes Station, show that the temperature structure of the air above the whole trail was almost identical with that above Wilkes Station and that no appreciable inversion existed.

Line					
1.	Day (1958)	14 Nov.	meters	16 Nov.	meters
2.	Time, Greenwich (Local standard plus 7 hours)	0600		0800	
3.	Corrected pressure at S-2 (converted to ft. by Smithsonian Table 51)	4610	1405	4710	1436
4.	Corrected pressure at Base (converted to ft. by Smithsonian Table 51)	565	172	695	212
5.	Difference in pressure (in ft.)	4045	1233	4015	1224
6.	Air temperature at S-2	15°F		15°F	
7.	Mean temperature of air up to S-2 pressure (Base upper air sounding)	17.6°F		22.1°F	
8.	Line 5 corrected for temperature (Smiths. 52)	3787	1154	3795	1157
9.	Correction for humidity (Base upper air sounding and Smiths. 54)	+6	+2	+6	+2
10.	Correction for gravity with latitude (Smiths. 53)	+6	+2	+6	+2
11.	Correction for gravity with altitude (Smiths. 55)	+1		+1	
12.	Correction for pressure gradient	0		-26	-8
13.	Correction for horizontal changes of temperature and humidity	0		0	
14.	Bernouilli correction	0		0	
15.	Approximate height of Base barograph above M. S. L.	35	11	35	11
16.	Total, lines 8 - 15 = height of S-2	3835	1169	3817	1163

For the purpose of this report the height of S-2 is taken as the mean, 3826 ft. (1166 m), of the two results above. Without more readings it is difficult to suggest the accuracy of this result. The largest sources of error are likely to be

(i) in the altimeter reading at S-2 (< 10 ft./3 m)

(ii) in the mean temperature of the air column between Base and S-2 (1^oF temperature error would cause 8 ft. (2 m) height error)

(iii) in the correction for the pressure gradient

With these in mind it appears that the error in this particular calculation is likely to be less than 50 ft. (15 m) and that with more readings this could be reduced to 20 ft. (6 m).

The figure of 3826 ft. may be compared with figures obtained by S/Ldr. D. Leckie, RAAF, on three flights between Wilkes Station and S-2 in January, 1959. On these flights the aircraft altimeter was corrected at Base for sea-level pressure, and the reading at S-2 corrected for the mean air temperature between Base and S-2. The heights so obtained were 3850, 3800, and 3800 ft. The calibration of the altimeter used is not known, but 15 ft. should probably be added to these figures as humidity and gravity corrections. The flights were made in less than 40 minutes, in anticyclonic conditions in midsummer, so that other corrections are probably minor. The mean of these results therefore is 3832 ft. (1168 m).

The help of Mr. J. Kangos and Dr. J. Shaw in this height determination is gratefully acknowledged.

c. Elevations between S-1 and S-2 (Hollin)

These elevations have been measured by simple altimetry (temperature correction only) and adjusted to the more accurately determined heights of S-1 and S-2. Altimeter readings were obtained in the course of two leapfrog journeys: one on 15, 16, and 17 April (see Section II-B-10 above), and one on 16 and 17 November. On the three-day April journey, stations were occupied on the average every 1-1/4 miles (2 km). On the 12-hour November journey, stops were made at 5 mile (8 km) flags only. For the final table of elevations the April values for the stations between 5 mile flags have been adjusted to the November values for the 5 mile flags, and these in turn have been adjusted to the previously determined values for S-1 and S-2.

The values obtained are tabulated below in feet (the altimeter units):

1. Interval	2. April value	3. Nov. value	4. Nov. value adjusted to S-1 (859') and S-2 (3826')	5. Final height intervals for April stations (incorporated in the Table of elevations)
S-2-S40	219	233	245	245
S40-S38	247	237	248	137, 111
S38-S35	230	224	235	120, 88, 27
S35-S32	252	261	273	59, 165, 49
S32-S30	292	280	293	200, 93
S30-S26	324	308	323	53, 66, 30, 174
S26-S21	312	309	324	89, 30, 90, 74, 41
S21-S14	339	338	354	34, 58, 31, 43, 26, 85, 77
S14-S-1	669	641	672	137, 65, 92, 85, 102, 47, 44, 44, 56

Note that the elevation of S-2 as a sum of nine 5-mile (8 km) increments plus the height of S-1 works out as only 3743 ft. (1141 m) for April and 3690 ft. (1125 m) for November, as compared with the previously determined height of 3826 ft. (1166 m). Some 30 ft. (9 m) of these discrepancies can be traced to temperature, humidity, and gravity corrections but the remainder is presumably the result of pressure gradient effects which cannot be corrected for by simple altimetry.

In adjusting the elevations between S-1 and S-2 the assumption has had to be made that the pressure gradient between those two points was constant throughout each altimetry journey. In fact, it can be deduced from observations of the weather at the time that the pressure gradient was not constant. Consequently the possible errors of elevation between S-1 (± 10 ft./3 m) and S-2 (± 50 ft./15 m) cannot be easily interpolated, and they probably remain as high as 50 ft. (15 m) for at least halfway down the trail. Nevertheless, in spite of these possibly large absolute errors the relative height of adjacent points in the altimetry survey is unlikely to be in error by more than a few feet. The order of magnitude of the possible errors between adjacent 5 mile (8 km) flags can be seen by comparing the values obtained by different methods in columns 2, 3, and 4 of the table above.

Future workers may note that the elevations below S-1 (several km inland) were not determined by pressure methods, and that an obstacle to altimetry at the margin of the Antarctic ice sheet is presented by the pressure jumps of 2 or 3 millibars associated with the seaward termination of katabatic winds. These jumps and the phenomena associated with them (roll-type clouds and a line of blowing snow a short distance inland) were frequently observed at Wilkes Station and have been described by Flowers (1958). The theory of the jumps has been discussed by Ball (1956).

16. Data from 1959

Two sets of aerial photographs of the Windmill Islands area were taken in 1959. During the take-over period in January-February, 1959, vertical coverage of the Northern Area in particular was obtained by Cronk, using a U. S. Navy Camera mounted in an Australian Auster aircraft. Prints from this operation and a record of the flight lines are held at The Ohio State University. These prints are the chief source of the detail recorded in the Northern Area map (Fig. 11). On 3 December 1959, in the course of a flight from McMurdo Sound to Wilkes Station, trimetrogon coverage of the shear moraine in particular was obtained by U. S. Navy aircraft of squadron VX-6. Negatives from this flight are held at the U. S. Geological Survey.

C. RESULTS

As much as possible of the work described in the preceding sections has been incorporated in three maps and a table of elevations. In addition, positions and elevations between Wilkes Station and S-2 have been plotted on the two profiles appended to Section IV (Figs. 21 and 22).

1. Maps

a. Wilkes Station location map (Fig. 1)

This map covers the area of operations of the 1957 and 1958 glaciological parties. The letters on the traverse route refer to camps on the traverse. The spot height (520 meters) inland from the Windmill Islands is approximate and was obtained by altimetry en route to Haupt Nunatak. The position of the Hatch Islets has been taken from maps based on Operations Highjump and Windmill. An astronomical determination of the islets' position was made by the Australian National Antarctic Research Expedition early in 1960.

b. The Windmill Islands (Fig. 10)

This map includes only a limited amount of detail, and should be used in conjunction with Hydrographic Office Chart 6669 (on which it is based) and the Northern Area map (Fig. 11). The position of the Frazier and Chappel Islets has been taken from the Russian map Q-49-77, 78 (1:100,000). The various rock outcrops east and southeast of Browning Island are shown comprehensively and accurately for what is believed to be the first time. "U" means an unofficial name. "P. D." means position doubtful.

c. Northern Area map (Fig. 11, in pocket)

This map has been designed primarily to illustrate the investigations of 1958, and to provide future workers with coverage of an area not included in the Hydrographic Office 1:12,000 charts of the region. It has been compiled on a scale of 1:12,000, but reduced to 1:24,000 for distribution purposes. The map has been designed to overlap the northernmost of the H.O. 1:12,000 charts (No. 6656), and the Mercator projection used has been continued northward from that chart. The map incorporates data from surveys 1, 2, 5, 6, 7, 8, and 9 of 1958. The positions of the accumulation-ablation stakes were fixed by transit and weasel odometer by Cronk in 1959. The positions of the "W" points, obtained from the 1957 party, have been fixed graphically only, and points at the edge of the map may be incorrectly placed by as much as 1/4 mile (0.4 km). Details on the map have been taken from the aerial photographs taken by Cronk in January, 1959, and by Squadron VX-6 in December, 1959. In the absence of contouring, rock patches have been marked "R" as a guide to travellers and help to workers in the area. Upper case letters in circles refer to sections of the moraine, discussed in the report on glacial geology. The streams marked on the map do not flow during the winter, and the lakes freeze over. However, the large lake immediately east of Wilkes Station remained unfrozen at depth, and provided the station water supply throughout 1958. The elevations of points marked on the map are included in the table below. With the exception of "Wilkes Station", names used on the map are provisional, and represent common usage during 1958. It is expected that a more accurate map of this area will eventually be made by either the Hydrographic Office or the Geological Survey.

2. Table of elevations

Point		Elevation above M.S.L. feet	meters
a.	Bench marks levelled twice from the tide gauge by D. Eyres		
BM	Top of hexagonal rod, 10 m inland from the tide gauge and 150 m N of Base	12.66	3.86
Gravity station	Base of hexagonal brass rod 60 cm high, 1.2 m W of the old seismograph shelter (NE of Base)	35.70	10.88
B2	Base of rod 1 m high, on crest of ridge between tide gauge and Base, nearer the latter	45.48	13.86

b. Levelled by D. Eyres

B3		73.23	22.32
G3		129.13	39.36
G6		57.66	17.57
G7		71.97	21.94
W1		76.45	23.30
W2		77.12	23.51
W4		110.59	33.71
W10	(Plane table survey by Robertson)	65.0	20.0

c. Triangulated in 1957

G4		99.38	30.29
G5		115.05	35.07

d. From Survey (15) (a)

2	2 to C6 rounded off to nearest ft. and meter	96	29
C9		45	14
3		104	32
C8		65	20
4		149	45
C7		145	44
C6		174	53
C6	Gravity flag	168	51
5		452.08	137.79
GN	Grinnell Nunatak (1957 marker)	154.75	47.17
C5	Gravity station on Nunatak	147.96	45.10
C4	C4 and C1 rounded off to nearest ft. and meter	169	52
C3		353	108
C2		430	131
B14		467	142
C1		529	161
A1		557.86	170
B13	B13 onwards rounded off to nearest ft. and meter	575	175
B12		651	198
406		721	220
B11		742	226
B10		804	245
B9	S-1 weather station, S5, A9	859	262

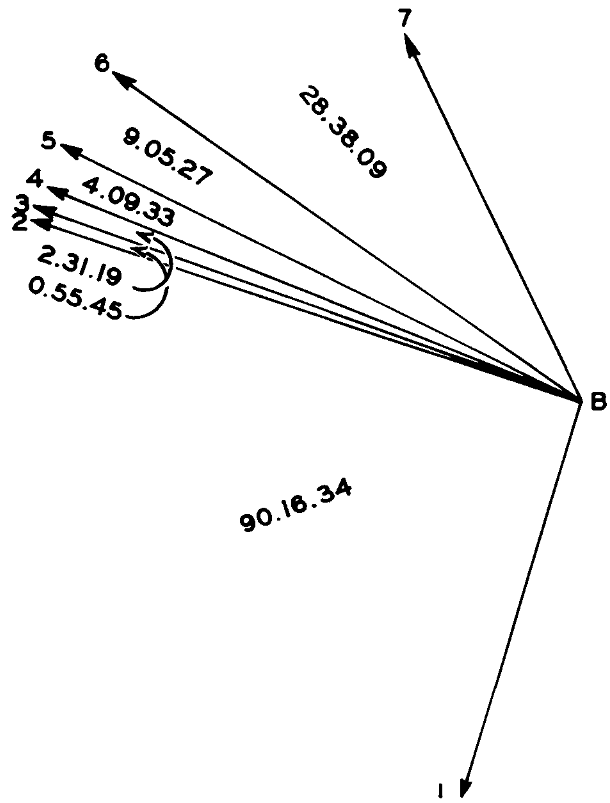
e. From Survey (15) (c)

B8		This value by subtense	923	281
B7	S6	988 by subtense 301 m	996	304
B6	S7	1052 " " 321	1061	323
F2B	Flag No. 2 barrel	1121 " " 342	1132	345
B3		1193 " " 364	1204	366
S8			1153	351
S9	150 m downhill from Black Flag 2		1238	377
BF2	Black Flag 2		1250	381
S10			1340	408
S11			1387	423
S12			1431	436
S13			1475	450
S14	"Mile 10", Red Flag 8, A3		1531	467
S15			1565	477
S16			1623	495
S17			1654	504
S18			1697	517
S19			1723	525
S20			1808	551
S21	"Mile 15", Red Flag 7, A4		1885	574
S22			1974	602
S23			2004	611
S24			2094	638
S25			2168	661
S26	"Mile 20", Red Flag 6, A5		2209	673
S27			2262	689
S28			2328	710
S29			2358	719
S30	"Mile 25", Red Flag 5, A6		2532	772
S31			2732	833
S32	"Mile 30", Red Flag 4, A7		2825	861
S33			2884	879
S34			3049	929
S35	"Mile 35", Red Flag 3, A8		3098	944
S36			3218	981
S37			3306	1008
S38	"Mile 40", Red Flag 2, A9		3333	1016
S38a				
S39			3470	1058
S40	"Mile 45", Red Flag 1		3581	1091

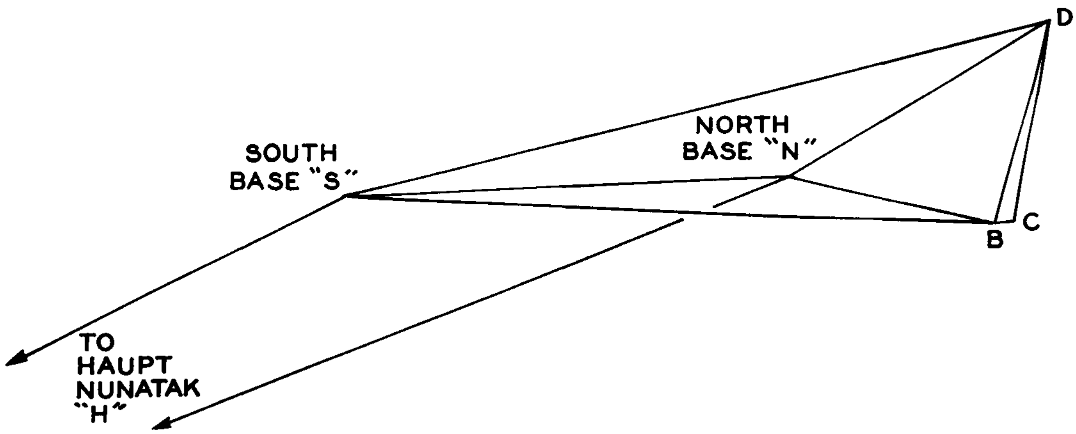
f. From Survey (15) (b)

S41	S-2.	On the triangular mast, 10 rungs below the lamp and 6 rungs above the ground on 17 April 1958	3826	1166

Fig. 6. Triangulation of Southern Area and Haupt Nunatak.
(a) Horizontal angles from Point B, in degrees, minutes and seconds.



(b) Position of points in Haupt Nunatak triangulation



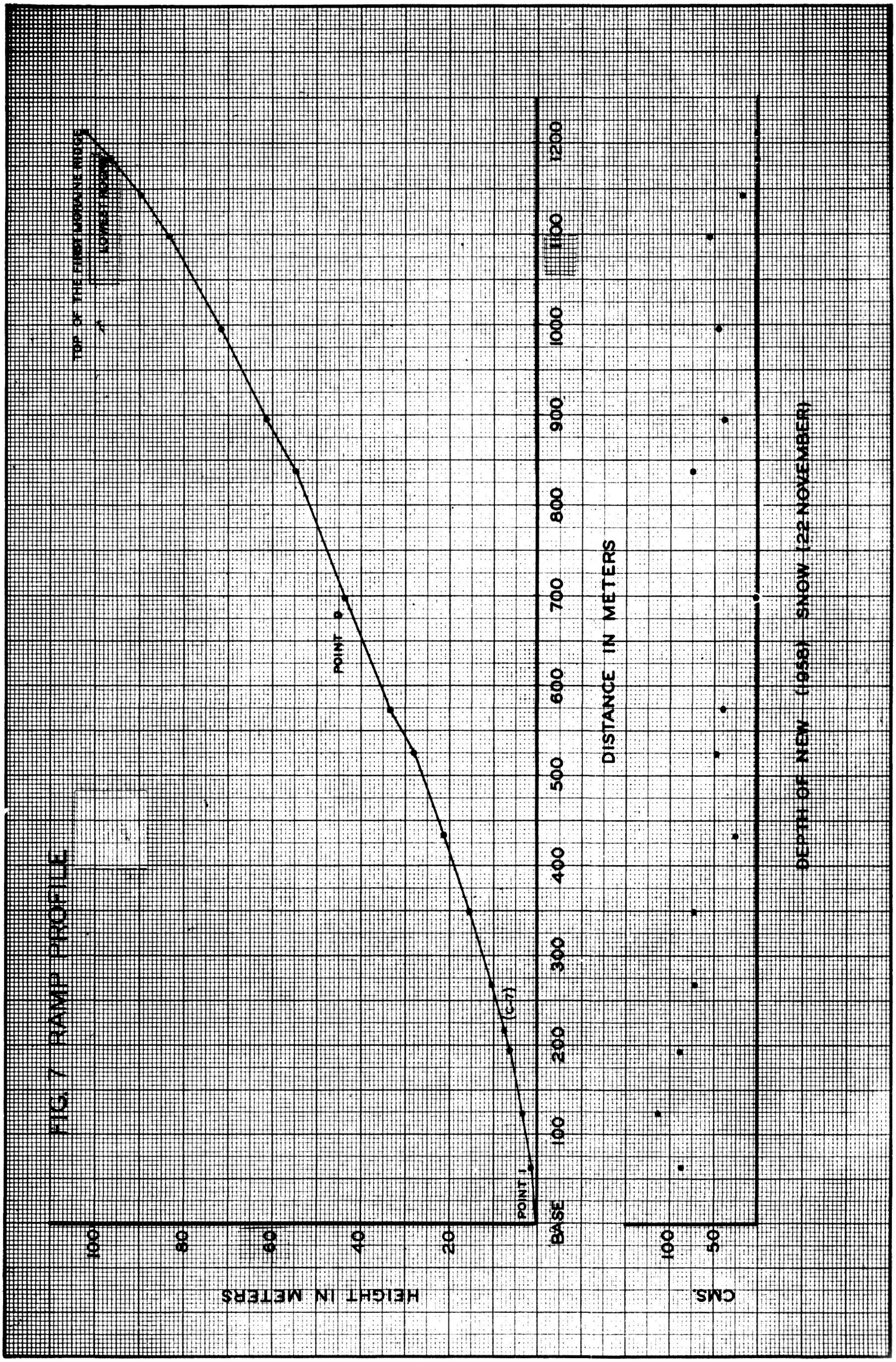


FIG. 7 RAMP PROFILE
TOP OF THE FIRST MORAINE RIDGE
POINT 1
(C-7)
HEIGHT IN METERS
100
80
60
40
20
BASE
100
200
300
400
500
600
700
800
900
1000
1100
1200
DISTANCE IN METERS
DEPTH OF NEW (1958) SNOW (22 NOVEMBER)
CMS.
100
50

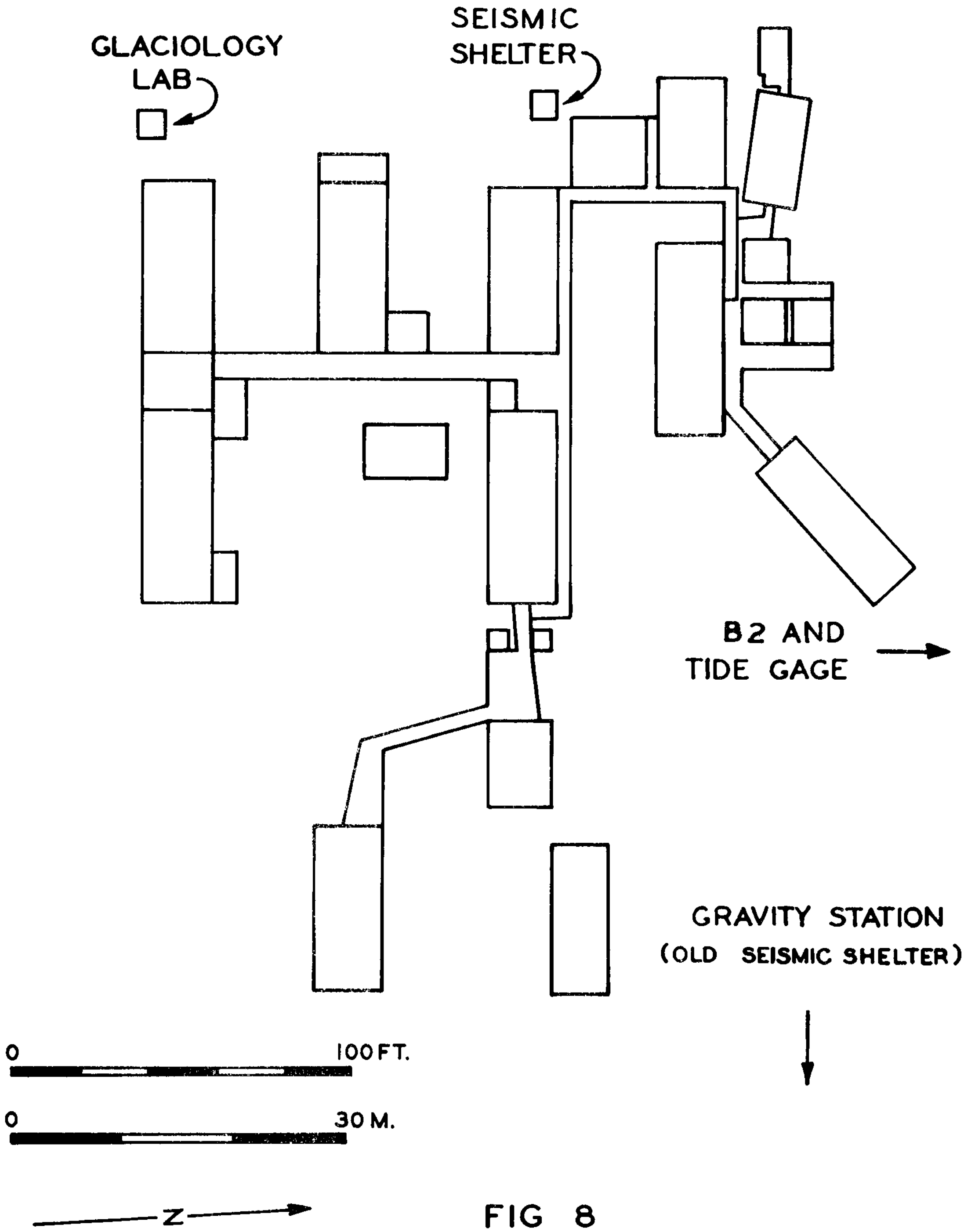


FIG 8
WILKES STATION
(DRAWN IN 1958 BY D. EYRES)

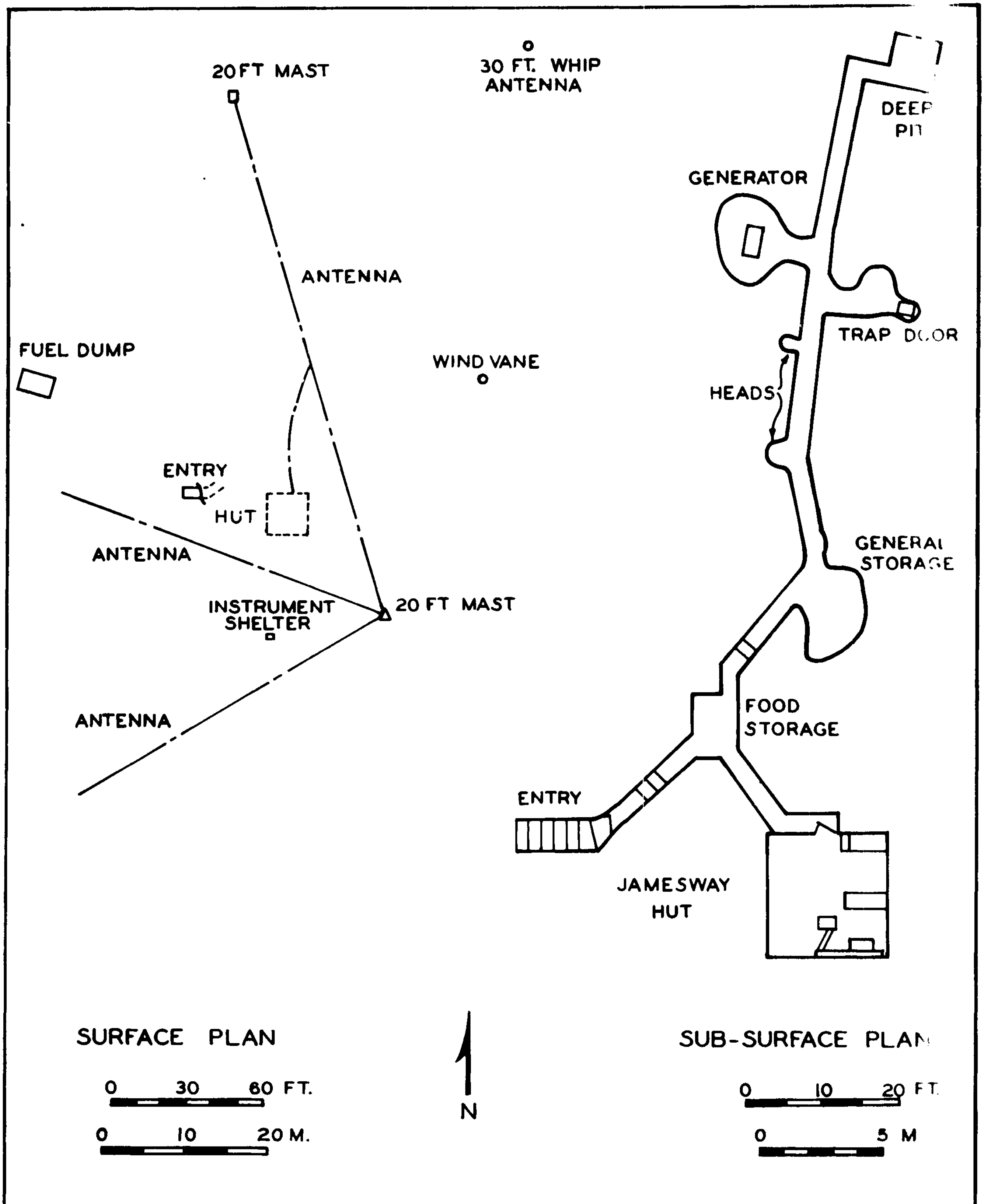
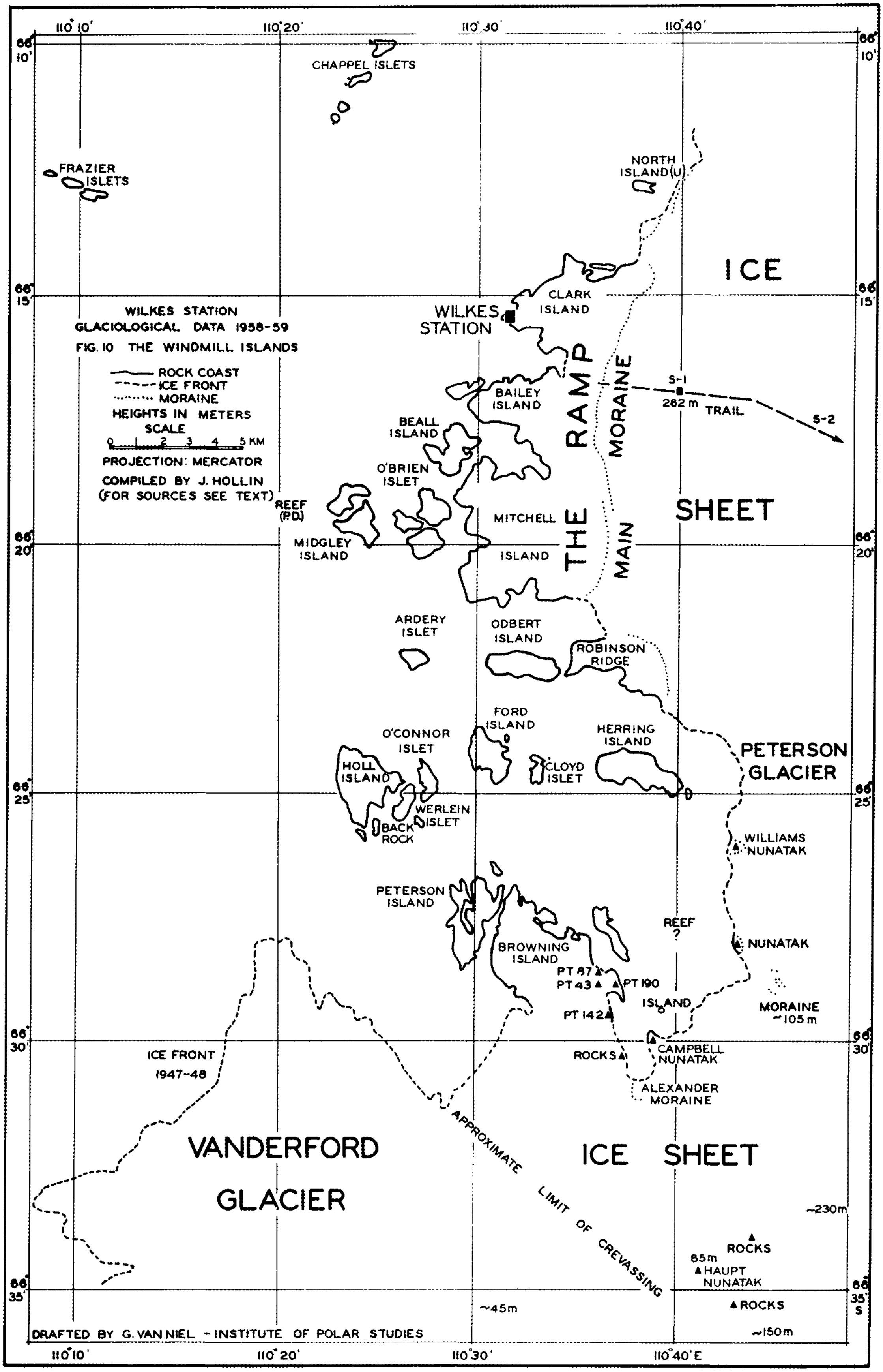


FIG 9
S-2
SURVEYED IN 1958 BY D. EYRES


WILKES STATION
GLACIOLOGICAL DATA 1958-59
FIG. 10 THE WINDMILL ISLANDS
ROCK COAST
ICE FRONT
MORAINE
HEIGHTS IN METERS
SCALE
0 1 2 3 4 5 KM
PROJECTION: MERCATOR
COMPILED BY J. HOLLIN
(FOR SOURCES SEE TEXT)
CHAPPEL ISLETS
FRAZIER ISLETS
NORTH ISLAND(U)
ICE SHEET
CLARK ISLAND
WILKES STATION
THE RAMP
MAIN MORAINE
S-1
262 m
TRAIL
S-2
BAILEY ISLAND
BEALL ISLAND
O'BRIEN ISLET
REEF (PD)
MITCHELL ISLAND
MIDGLEY ISLAND
ARDERY ISLET
ODBERT ISLAND
ROBINSON RIDGE
FORD ISLAND
O'CONNOR ISLET
HERRING ISLAND
PETERSON GLACIER
HOLL ISLAND
CLOYD ISLET
WERLEIN ISLET
BACK ROCK
WILLIAMS NUNATAK
PETERSON ISLAND
REEF ?
NUNATAK
BROWNING ISLAND
PT 87
PT 43
PT 190
PT 142
ISLAND
MORAINE ~105 m
ROCKS
CAMPBELL NUNATAK
ALEXANDER MORAINE
ICE FRONT 1947-48
VANDERFORD GLACIER
APPROXIMATE LIMIT OF CREVASSING
ICE SHEET
~230m
ROCKS
85m
HAUPT NUNATAK
ROCKS
~45m
~150m
DRAFTED BY G. VAN NIEL - INSTITUTE OF POLAR STUDIES
110°10'
110°20'
110°30'
110°40'
110°40' E
66° 10'
66° 15'
66° 20'
66° 25'
66° 30'
66° 35'
66° 35' S

III. MOVEMENT SURVEYS

A. THE VANDERFORD GLACIER (Cronk)

These measurements continue directly from those of 1957. Observations were made with a Kern DKM2 theodolite in March and a Wild T2 theodolite in November. The stake coordinates tabulated below have been calculated using the 1957 value for the base line (A - B) at Haupt Nunatak. The positions of points A and B are shown in Fig. 5. Point A is a small cairn (with a range pole inserted) approximately 5 m below and 20 m west of the larger summit cairn of Section II-B-4. Its elevation, therefore, is approximately 80 m, but for the height coordinates of this survey the arbitrary height of 200 m has been carried over from the Report for 1957. During the March visit to the glacier several stakes were replaced by fresh 2 x 4-inch timbers. Stakes 4 and 10B could not be located, and a new stake "4A" was inserted. In November Stake 8A could not be located. Also presented below are more angles between A and three wave crests on the glacier. Figure 12, an aerial photograph taken early in 1959, shows several of these wave crests. Complete aerial photographs of the Vanderford Glacier have been taken by the U. S. Navy and the Australian National Antarctic Research Expeditions, whose photograph 9237 is particularly illustrative.

Movement Stake Coordinates

Date	Stake	X(m)	Y(m)	h(m)*
6 - 7 March 1958	1	568.4	237.6	169.4
	4A	706.4	831.8	157.3
	5	869.0	1431.6	151.0
	6	931.1	1590.8	161.2
	7	1175.5	1818.4	160.1
	8A	1065.4	2096.9	162.8
	8B	1161.8	2498.4	164.7
	9	1279.5	3113.4	174.9
	10A	2167.4	3846.3	175.2
	11	3024.5	4547.3	196.0
30 November 1958	1	567.7	238.3	169.25
	4A	705.7	829.7	157.0
	5	924.5	1398.2	150.0
	6	1013.0	1550.1	161.7
	7	1312.1	1779.4	160.8
	8B	1444.7	2442.0	160.4
	9	1722.6	3010.3	175.5
	10A	2713.7	3760.4	175.1
	11	3615.3	4484.3	194.2

*See paragraph above

Angles Between A and Wave Crests

Date	Crest	Horizontal Angle	Vertical Angle
6 - 7 March 1958	1	105°42'	+28'
	2	122°40'	+18'
	3	135°04'	+12'
30 November 1958	1	110°12'	+28'
	2	126°53'	+17.5'
	3	138°20.5'	+11.5'

B. THE VANDERFORD GLACIER - HOURLY OBSERVATIONS (Cronk)

On 1 December 1958, hourly observations were made to determine whether or not the flow of the Vanderford Glacier exhibited any short period irregularities. Readings were made with a Wild T2 theodolite from Point B on Haupt Nunatak to (1) a well-defined ice point on the skyline of the glacier and (2) Stake 9. Observations of each were begun as soon as there was enough light. To 0800 inclusive only one reading of each angle was taken, but after 0900 inclusive both erect and inverted readings were taken. The results are listed below (change since previous observation of angle relative to Point A in seconds), and plotted cumulatively in Fig. 13 (total angular displacement in seconds).

Instrument at B
Change since previous observation of angles relative to A, in seconds

Time	Ice point	Stake 9
0400	+ 7	
0500	0	
0600	- 5	
0700	+11	
0800	+ 2	+ 1
0900	+10	+11
1000	+ 2	+ 3
1100	+ 5	+ 5
1200	- 3	- 1
1300	+ 3	+ 8
1400	+ 6	0
1500	- 1	+ 3
1600	+ 6	+ 7
1700	+ 2	+ 6
1800	+ 5	+ 8
1900	- 1	+ 6
2000	0	- 5
2100	+ 3	+ 3
2200	- 4	- 1

Three facts are apparent from these measurements:

1. Although the ice point was nearer than Stake 9 to the center of the glacier, it was nevertheless moving slowly at the time of the survey.

2. The total movement of Stake 9 between 0700 and 2200 hrs. was at a rate of 1.36 m per day, compared with an average of 1.65 m per day for the whole period between March 1957 and November 1958.

3. It appears that the irregularity of the lines in Fig. 13 may represent observational errors rather than irregular ice motion. The mean difference between Face Right and Face Left readings in the survey is three seconds for Stake 9 and four seconds for the ice point, with a maximum difference of twelve seconds. Within these limits of accuracy the graphs in Fig. 13 cannot be said to differ significantly from straight lines.

C. CAPE FOLGER (Hollin)

A survey of the movement of this ice cape was begun in March 1958 by Dr. Willis Tressler and Lt. Eyres, USN. A theodolite position F1 was established between the glaciology laboratory and the direction finder antenna. The distance between this point and Cape Folger was found by triangulation from points on Clark Island to be 9.94 miles (16.00 km). From F1 the change in angle between F2 (a fixed point on the peninsula to the north of Tide Gage Cove) and Cape Folger was measured at intervals, and the movement of the Cape calculated from the change and the known distance. Obviously the movement calculated was only that in a direction at a right angle to the line of observation. However, the general configuration of the coast in this area suggests that this direction is unlikely to vary more than 15^{o} from that of absolute movement. On 26 August Cape Folger was reached via the sea ice and climbed with the aid of a ladder. Beacons were erected approximately 75 and 600 m inland from the Cape, and their movement also measured.

The data below are abstracted from a longer report by Tressler (1960a). Before any conclusions are reached concerning seasonal changes in movement or the relative displacements of the surveyed points, the longer report should be checked to find the limits of accuracy involved.

Average movement in feet per day

Date	Cape Folger	Seaward beacon	Inland beacon
25 Mar	1.42		
2 Apr	0.51		

Date	Cape Folger	Seaward beacon	Inland beacon
12 Apr			
	0.36		
19 Apr			
	0.45		
27 May			
	0.50		
19 Aug			
	0.32		
6 Sept			
	0.52	0.47	0.82
6 Oct			
	0.29	0.42	0.39
4 Nov			
	0.66	0.54	0.39
20 Nov			
	0.38		0.47
23 Dec			
Whole period	0.48		

D. THE ICE SHEET NORTHEAST OF CLARK ISLAND
(Robertson, Cronk)

On 10 February 1958 stakes for a movement and accumulation survey were inserted northeast of Clark Island along a line marked on the Northern Area map (Fig. 11). This line was approximately 75 m above sea level. Split bamboos were set out at approximately 0.15 to 0.3 km intervals and aligned with each other by eye. The first stake (431, with two orange flags) was inserted at the northern end of the main shear moraine and was later used in Topographic survey (5). At Stake 437, the straight line was bent to the right. At the end of the line, Stake 455 was inserted on the brow of an ice slope overlooking a hollow of level ice which is probably afloat. This slope and some ice domes to the east were crevassed. Lineations parallel to the contours and suggestive of shearing were noticed several hundred meters east of 437.

These stakes were revisited on 24 December 1958, but many of them had lost their string tied tags and were difficult to identify. As had been planned, only appreciable relative movement could be measured. Stake 437 had probably moved forward a few centimeters. Two stakes (probably 451 and possibly 452) had moved forward between 0.6 and 0.9 m. What was possibly Stake 454 had moved forward approximately 1.8 m. Accumulation or ablation measurements on this profile are presented in Section VI-B-3.

E. A TRENCH IN THE SHEAR ZONE (Hollin)

On 5 April 1957, a trench was excavated across shear planes on the inland side of Shear Moraine Section C (see Fig. 11). Pegs inserted in the walls of this trench were measured at that time and remeasured by Hollin and Robertson on 3 May 1958. Both sets of measurements, which taken together show some movement, are on file at The Ohio State University. The ice of the trench walls had a grey color which appeared to be produced by dirt in the inland-dipping shear planes rather than by surface cryoconite. Crystals in the shear planes were observed under crossed polaroids and were less than 1 mm in diameter. The planes were bubble free. By now (1960), blown snow and melted water are likely to have filled this trench.

F. THE LOWER ICE SHEET AND RAMP (Hollin)

1. Introduction

This survey was designed to investigate the upward bending or shearing motion of the lower ice sheet and the Ramp. The pressure of other activities delayed the start of the survey until mid-winter 1958, but time was eventually found for the measurement of both horizontal and vertical motion. The horizontal survey was tied in to points on solid rock, but unfortunately there was no time to tie in the vertical survey, which is therefore only relative. For the furure it would be of considerable interest to tie in the vertical survey, and to extend both it and the horizontal one downhill to Grinnell Nunatak and uphill to S-1. Such an extension would add considerable value to any further ice-depth and temperature measurements which might be made in this area.

2. Description of the area

The points covered by this investigation are shown in plan on the Northern Area map (Fig. 11) and in profile on Fig. 14. In these figures the shear planes marked are those clearly visible on the ground, but there are probably others with less surface expression. Some N-S lineations further inland may be shears or may be sealed cracks (see Section VII-A-15). Ill-defined lineations on the ice at M1 have a bearing of 300°. The color changes marked on the figure are very pronounced on the ground. The change from light blue to dark blue ice may follow a shear plane or may represent the seaward limit of superimposed ice formed in the summer of 1957-58. The change from dark blue to grey ice occurs along a line which appears to be the uppermost shear plane with any significant quantity of debris, although further south the line looks more like a closed crevasse than a shear plane. To the north the line swings uphill near the trench (see map), becomes less straight, and is joined by the lowermost of the three shear planes below M2. In the area of the trench Cronk recorded two isolated areas of dark blue ice. M5 was inserted in a westward extension of the dark blue ice (see map).

Lower Base Moraine and Isolated Moraine are possibly on the same shear plane. Between them, and to the north of Lower Base Moraine, the ablated ice (visible between patches of superimposed ice) contains little dirt but has bubbles elongated approximately vertically and grouped in bands.

Stakes D, A, B, and C straddle the Isolated Moraine and an area of curved lineations illustrated in Fig. 15. Not enough time was available to investigate these lineations. A shallow pit excavated near Stake A contained elongated bubbles dipping 70° SE and cracks dipping 80° SSW.

3. Description of the points surveyed

Details of the points surveyed are listed below. Stakes 403, M1, M2, M3, M4, M5, 06, D, A, B, and C are all split bamboos inserted to approximately two meters. For the horizontal survey their bases were surveyed; for the vertical, their tops. The other points were established on boulders. Boulders were chosen that looked stable; however, any boulder on the moraines is subject to distrubance by the melting or sublimation of the ice below it. Any extension of this survey should include photographs of each boulder used and its surroundings.

Included in Horizontal Survey	Included in Vertical Survey	Stake	Description
	x	403	The northernmost of three close together (see Section VI-B-4
x	x	M1	~8 m E of A1. Top of M1 to base of A1 = 1.86 m vertically. A1 is ~ 10 m E of change in ice color.
	x	M2	
	x	M3	
x	x	M4	
x	x	M5	
	x	06	Also an accumulation stake.
	x	RHB	(Right hand boulder) Survey points are Xs chipped on top of each.
	x	CB	(Center boulder)
	x	LHB	(Left hand boulder)
x		UB	(Upper base) X chipped on flat rock
x	x	LB	(Lower base) X chipped on side of rock ~2 m ~ENE of the lower of two flags. Not known whether July vertical sight was to the "X" or to the top of the rock
	x	Y	X chipped on a 50 cm long rock ~3 m SE of peak close to Point 5.
	x	Z	The <u>top</u> of the third big rock from the south of the fresh looking ridge. The rock has an "X" chipped on its side.
	x	D	
x	x	A	Not to be confused with some markers inserted just to the south into cryoconite holes. The horizontally surveyed stake might just possibly be B or one of the markers: although there was no time to check this it was considered worthwhile to take the observation.
	x	B	
	x	C	

4. The horizontal survey (Cronk)

In July and December, a Wild T2 theodolite was established at Lower Base and Upper Base. Angles to G5, G8, Grinnell Nunatak, (three points on solid rock), the bases and M1 were measured twice erect and twice inverted, and to the other points in the horizontal survey once erect and once inverted. The flags at G5 and G8 were liable to move a few centimeters in the wind. Lower Base was sighted from Upper Base by erecting a tripod with plumb bob over the former, and vice versa.

The absolute position of Lower Base and Upper Base has been worked out by resection, using data recorded for future reference in Fig. 16. The position of the other points in the survey has been worked out by simple triangulation. The changes in position recorded are presented below in the form of cartesian coordinates.

	30-31 July 1958				19 December 1958			
	x		y		x		y	
	feet	meters	feet	meters	feet	meters	feet	meters
G8	0.0	0.0	0.0	0.0				
Gr. Nun.	0.0	0.0	4924.8	1501.08				
LB	4562.4	1390.62	4765.5	1452.53	4562.0	1390.50	4765.2	1452.44
UB	4419.3	1347.01	5804.8	1769.31	4418.3	1346.70	5804.6	1769.25
M1	5928.0	1806.86	5961.2	1816.98	5926.0	1806.25	5960.1	1816.64
M4	4953.1	1509.71	5640.7	1719.29	4952.6	1509.56	5640.2	1719.14
M5	4848.8	1477.92	5935.3	1809.08	4847.6	1477.55	5935.0	1808.99
A	3535.0	1077.47	5925.2	1806.00	3534.0	1077.17	5924.9	1805.91

These changes are presented graphically in Fig. 17.

5. The vertical survey (Hollin)

This survey is in two unconnected parts: one between 403 and Lower Base Moraine, and one in the area of the Isolated Moraine. The survey was made with a transit and rod. The results are presented below in feet and decimals of feet and in metric equivalents. Each interval of height was surveyed uphill and downhill, up to six times when necessary. The results have been averaged here to three places of decimals and, with three mentioned exceptions, should have an accuracy of ± 0.02 ft. (0.006 m).

Interval (Highest first)	16 June	26-27 June	21 July	31 July	27 Aug.	30 Dec.-2 Jan.	Remarks
403-M1				20.175(6.15)		19.600(5.97)	M1 possibly bent a little at second reading.(This would decrease 19.60 and increase 32.350)
M1-M2		32.033(9.76)				32.250(9.83)	
M2-M3		15.465(4.71)				15.495(4.72)	
M3-M4		28.205(8.60)				28.503(8.69)	
M4-M5			8.348(2.54)			8.348(2.54)	
M4-06			18.385(5.60)			18.370(5.60)	
M4-LHB			17.780(5.42)			17.785(5.42)	
M4-CB			17.640(5.38)			17.630(5.37)	
M4-RHB			18.600(5.67)			18.570(5.66)	
06-LB			1.150±0.150(0.35±0.05)	(not known whether sight was to X or to top)		1.08±0.12 (X) (0.33±0.04) 1.025±0.12 (top) (0.31±0.04)	
06-Y			22.228±0.050(6.78±0.02)			22.155(6.75)	
06-Z			29.203±0.050(8.90±0.02)			29.060(8.86)	
D-A					14.885(4.54)	14.800(4.51)	
A-B	16.038(4.89)					15.973(4.87)	
B-C	11.493(3.50)					11.545(3.52)	

G. THE GRINNELL GLACIER (Cronk)

The approximate positions of the six stakes of this survey are shown on the Northern Area map (Fig. 11). It should be stressed that the Grinnell "Glacier" is essentially a part of the Ramp, is uncrevassed except at its seaward edge, and is probably not more than 50 meters thick. Six stakes inserted into the Glacier in 1957 showed no movement during that year. In 1958, the stakes were inserted afresh and the angles between them and G5 measured from Grinnell Nunatak on 1 May and 1 December. Readings were made with a Wild T2 theodolite, positioned at the main survey point on the Nunatak. This point is marked by an iron rod drilled into the rock, and is approximately 1.2 meters NE of the 1957 survey position here.

The slight angular change recorded by December 1958, was in every case in the direction of lean of the stake, and was in no case big enough to indicate any definite movement of the whole stake. Note that the only movement which could be recorded was that at right angles to the line of sight from the Nunatak. Readings on 1 May are listed below for future reference.

G5		00°	00'	00.0"	
Base of Stake	1	79	53	44.6	
	2	79	53	26.7	
	3	79	54	01.8	
	4	79	54	02.2	(Disappeared by 1 Dec.)
	5	290	24	21.6	
	6	290	13	17.4	

H. A NETWORK AT S-2 (Cronk)

The distribution of the twelve 1-1/4-inch diameter bamboo stakes which form this network is shown in Figs. 18 and 19. Stake A is a few meters to the south of the triangular mast at S-2, and Stake B is approximately south of A. Details of the three surveys made here are outlined briefly below. The results of these surveys will be presented in a forthcoming paper. Meanwhile, as a guide to future workers, the provisional distances and horizontal and vertical measurements from 1957 are shown in Figs. 18 and 19.

<u>March 1957</u>

The network was established and first surveyed on 16, 18, and 20 March 1957. The instrument used was a transit reading to 30-seconds horizontally and one-minute vertically.

<u>May 1958</u>

An attempt to resurvey part of the network with a Wild T2 theodolite late in May was defeated by low temperatures and extreme refraction, and only triangle ABC was completely surveyed. This contained, however, a closure error of $1^{\circ}10'$.

January 1959

In this month the network was completely resurveyed. The baseline was measured with an Invar tape twice on each of two overcast days. On 8 January, plumb bobs were used on a few sastrugi, and the temperature during the observations varied between -6° and $-3^{\circ}C$. On 9 January, all obstructing sastrugi were levelled, and the temperature was approximately constant at $-2^{\circ}C$. The measurements recorded on 8 January were 1597.655 and 1597.520 meters; and on 9 January, 1597.685 and 1597.645 meters. These results include possible inaccuracies of +1.5 cms (temperature of tape), -1.5 cms (tension on tape), and +0.5 cms (slope of baseline).

Erect and inverted horizontal and vertical measurements were made with a Wild T2 theodolite on 10, 15, and 17 January. Vertical angles were read to the tops of stakes. The height of the stakes above the snow surface and the heights of the instrument were measured. Stations were occupied by bending the stakes aside in order to allow room for the instrument. These three days were clear and sunny, and there was much shimmer. Because of this and the relative rise of the snow surface some stakes had to be lengthened by the addition of a flag. In those cases (B to F, E to F, G to H, and F to E) the vertical angle to the top of the original stake had to be estimated. Reading G to F was handicapped by blowing snow. The line AJ and the angles on each side of it could not be measured because the S-2 station drift intervened. All the stakes were approximately vertical, so that distance errors due to the tilting of stakes are negligible.

Fig. 12. Vanderford Glacier from the air, looking SW.
Vincennes Bay is just to the right of the photograph.
Photograph by C. Cronk

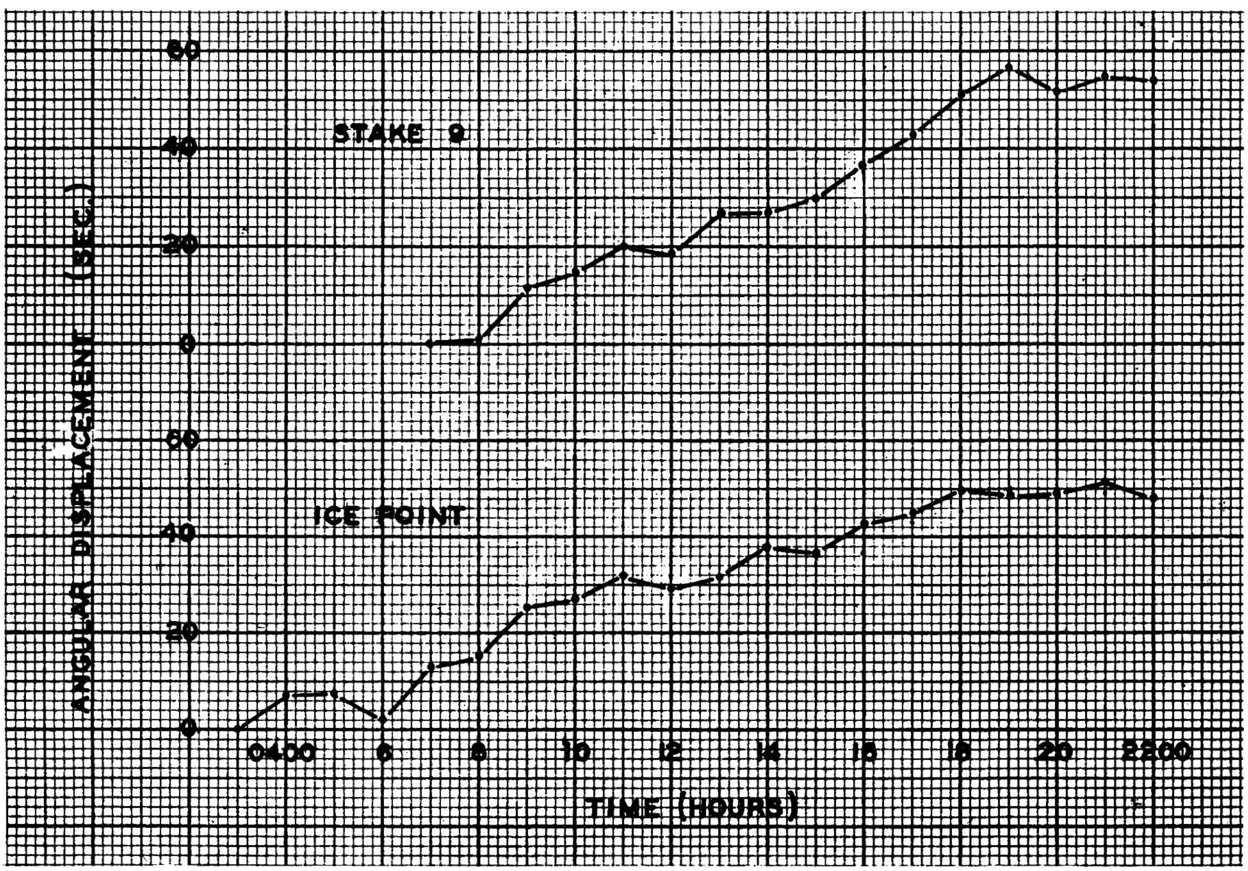


Fig. 13. Movement Survey B

MOVEMENT SURVEY F, PROFILE

FOR POSITION OF ALL POINTS SEE NORTHERN AREA MAP (FIG. 11)
HORIZONTAL POSITIONS OF M2, M3, D, B, AND C APPROXIMATE ONLY
HEIGHT OF "IM" RELATIVE TO "LB" NOT MEASURED

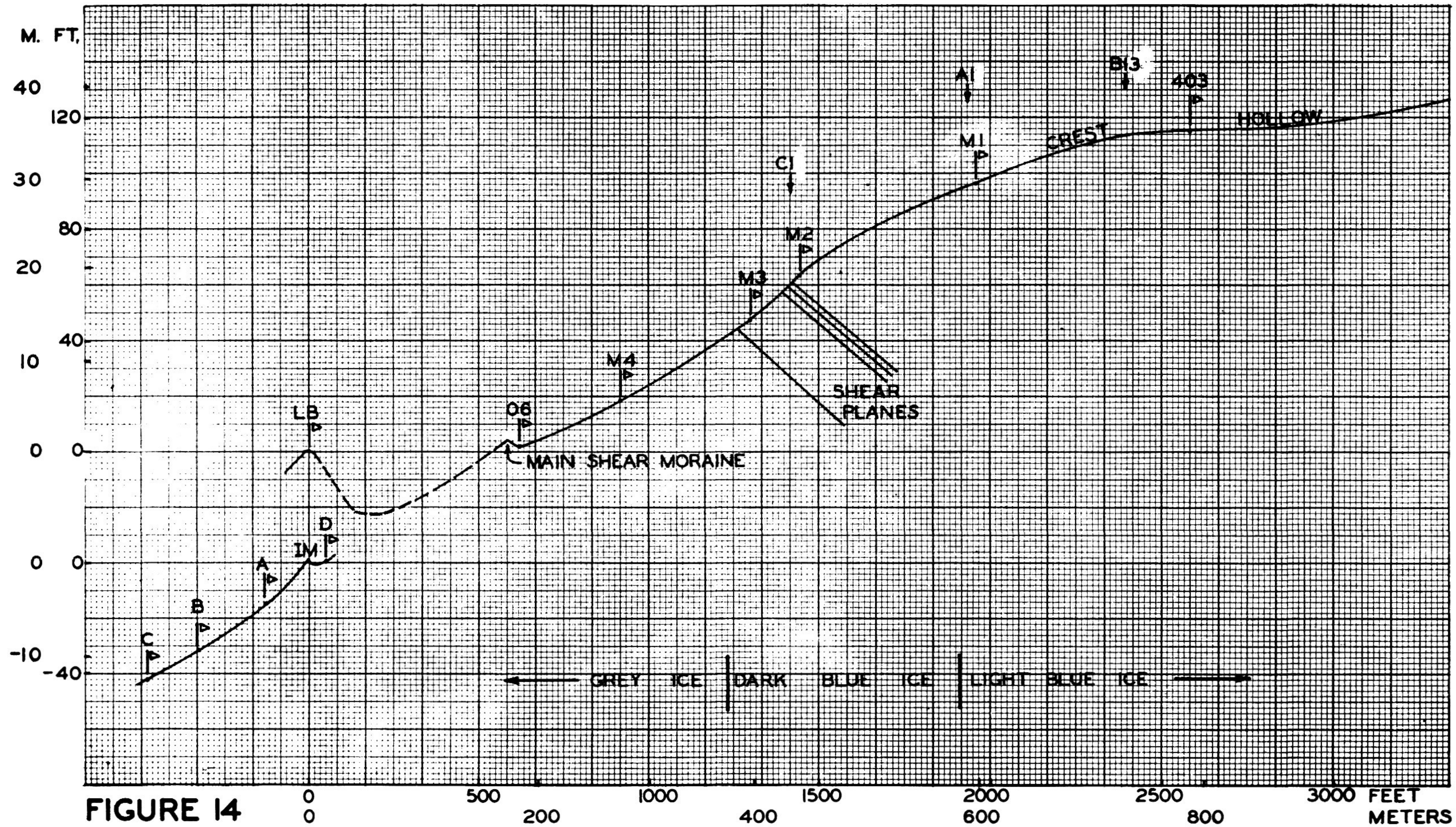


FIGURE 14

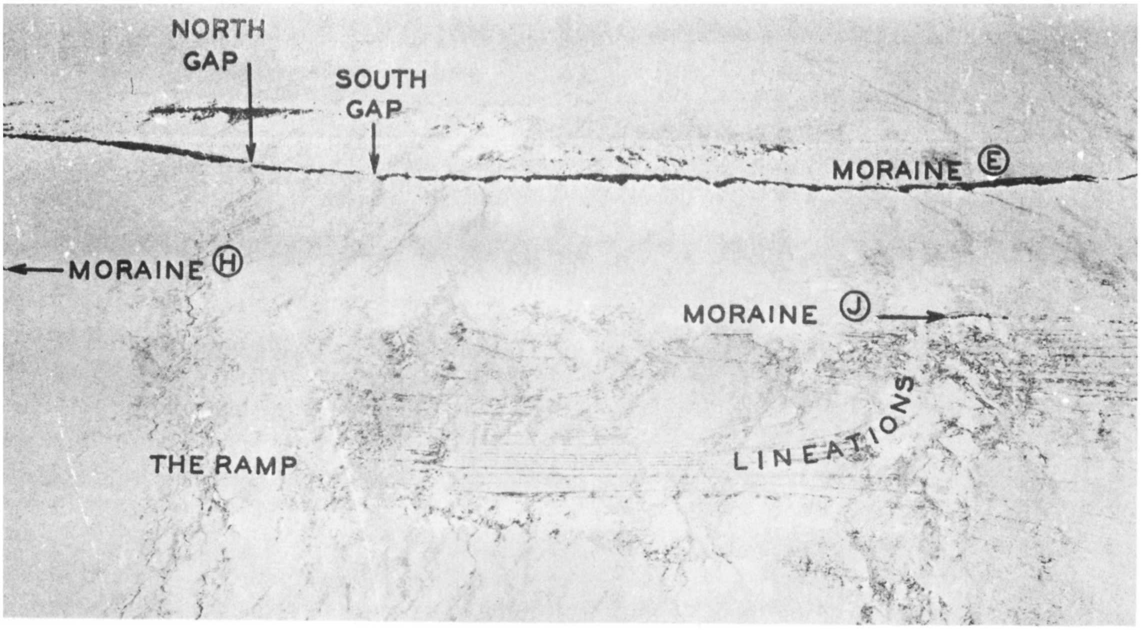


Fig. 15. Movement Survey F. Survey area from the air, looking E. Official photograph, U. S. Navy.

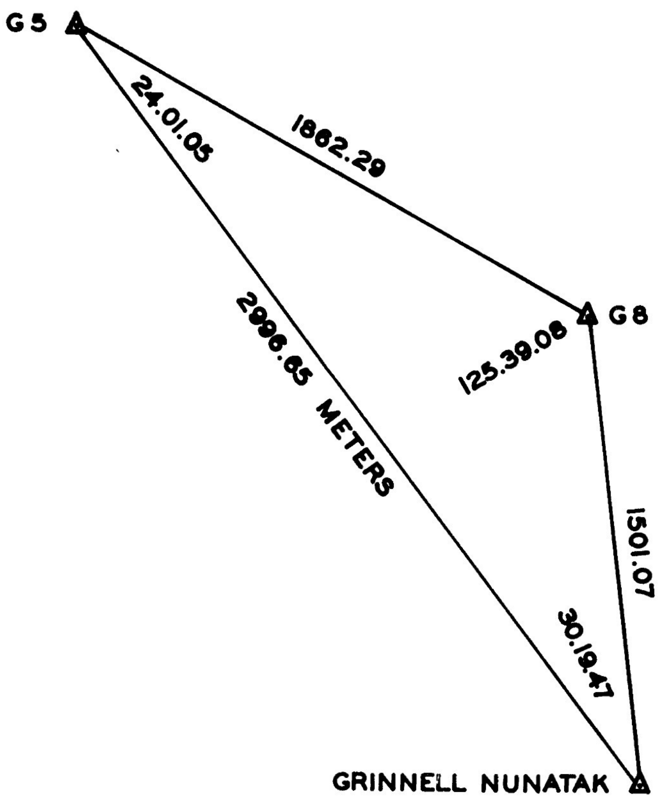


Fig. 16. Movement Survey F. Resection data. Angle in degrees, minutes and seconds. Distances in meters.

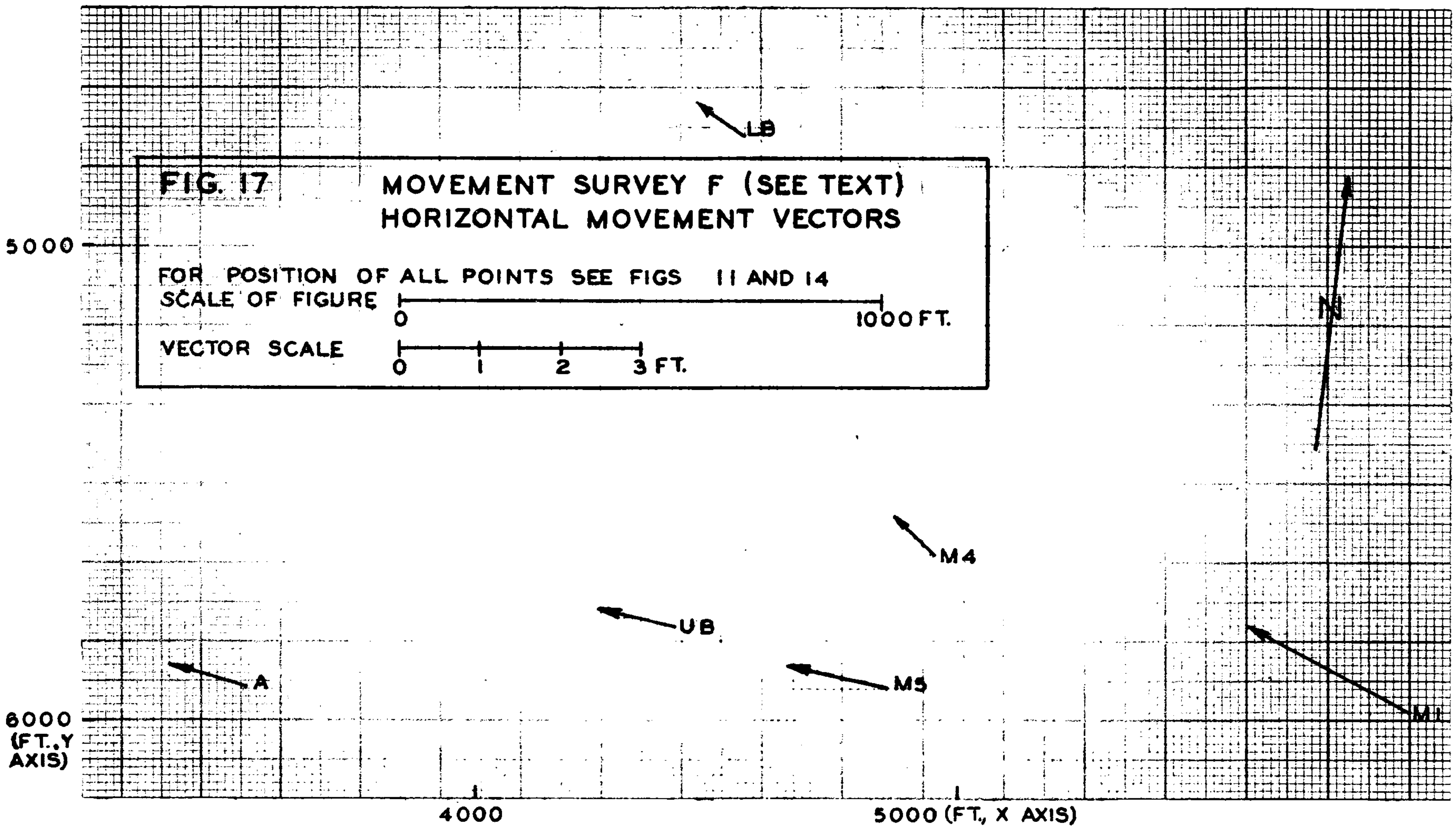


FIG. 17 MOVEMENT SURVEY F (SEE TEXT)
HORIZONTAL MOVEMENT VECTORS

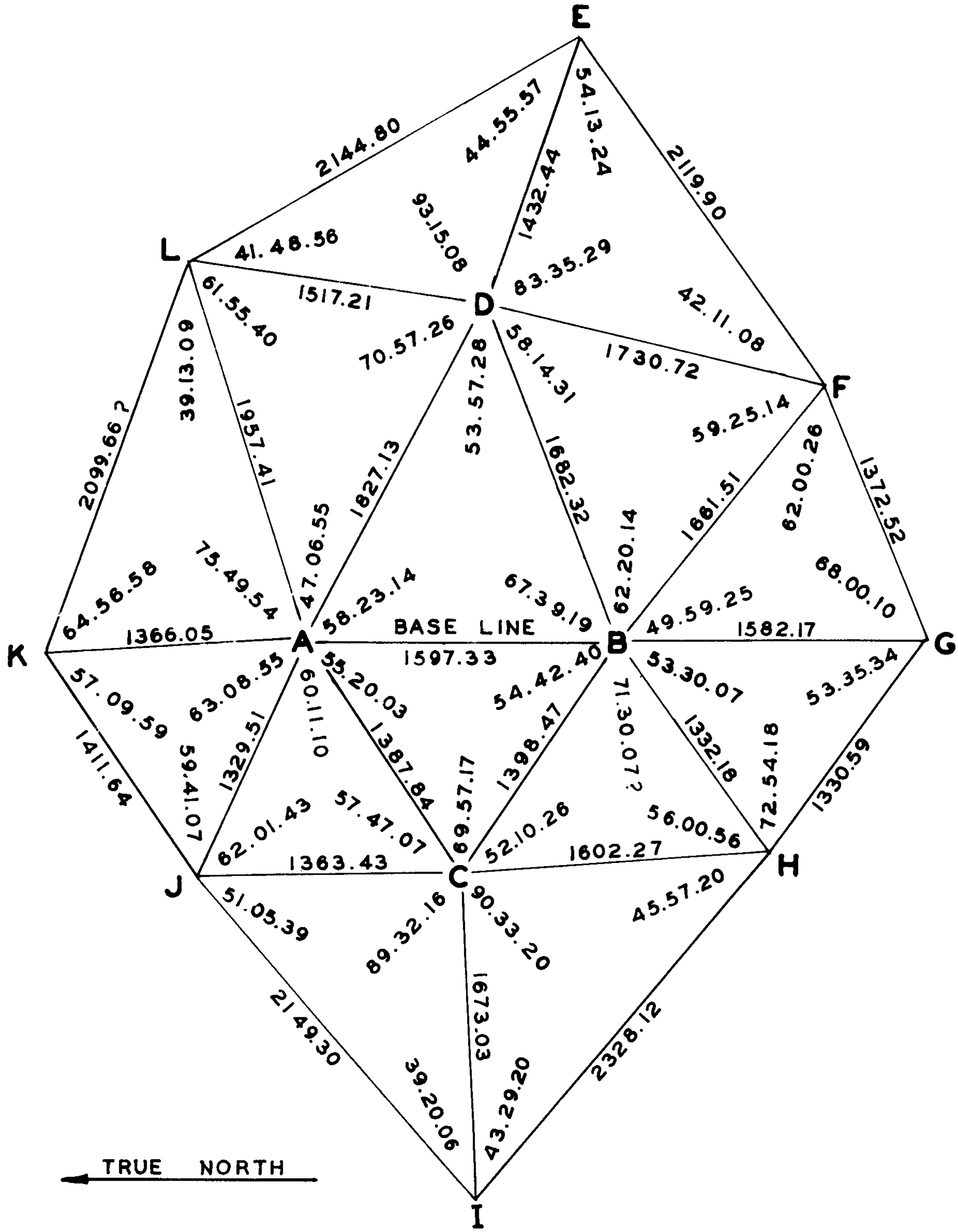


Fig. 18. Movement Survey H. March 1957. Horizontal angles in degrees, minutes and seconds. Distances in meters.

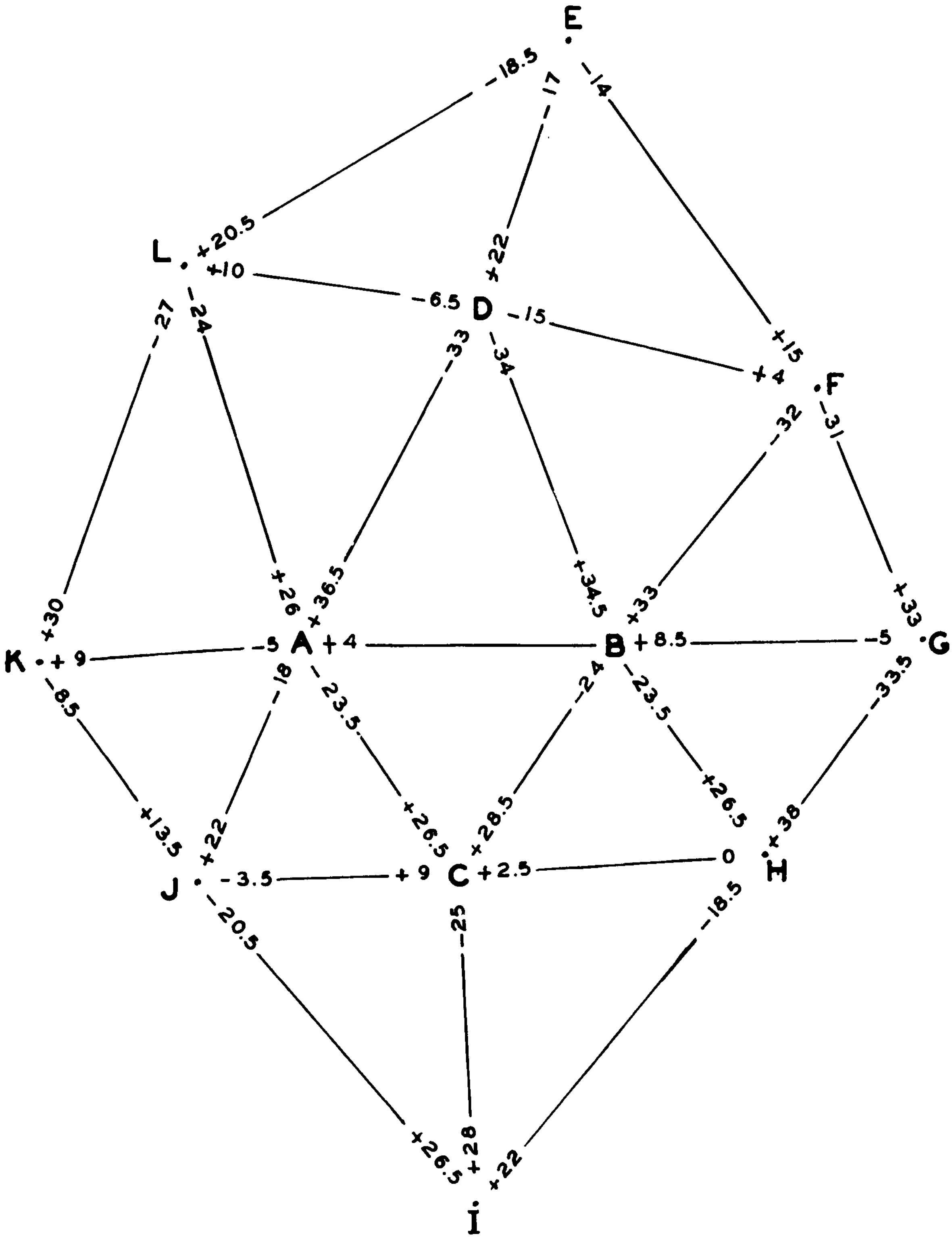


Fig. 19. Movement Survey H. March 1957. Vertical angles in minutes. Angles are away from stakes. Angles in minutes.

IV. GRAVITY SURVEY

A. THE SURVEY (Hollin)

Gravity measurements in the Wilkes Station area were made in January 1958, by J. Sparkman of the University of Wisconsin, in the course of a mission designed primarily to establish gravity base stations in the Pacific and Indian Ocean sectors of Antarctica. The principal results of this and similar missions have been described elsewhere (Thiel, 1959). The instrument used was LaCoste No. 1 geodetic meter.

Gravity values were measured at Base and, to assist the glaciological party, at various points on the trail to S-2. Firstly, on an outward journey to Mile 40 (Km 65.6), stations labelled "A" were established at each five-mile (8 km) flag. Secondly, on the return from Mile 40, stations labelled "B" were established approximately every 1/3 mile (1/2 km) below Mile 8 (Km 13). Thirdly, stations labelled "C" were established on the Ramp and on the rock of Clark Island. "A2" is the same station as "B9". The positions and elevations of the stations were surveyed by the glaciological party and are shown on Figs. 11, 21, and 22. The flags inserted to mark B1, B2, B4, and B5 disappeared before they could be surveyed, so that the gravity values obtained at those points cannot be used.

The conversion of gravity values to ice thicknesses is helped by the great density contrast between ice and rock. The chief problem in such conversions is that of allowing for subglacial rock density and isostatic changes, which may have the same gravity effect as ice thickness changes. This problem is solved in most Antarctic work by seismic checks on thickness. At Wilkes Station, however, seismic equipment was not available, and in its absence the following procedures have been adopted: the first as far as B3 (5 miles (8 km) on the ice sheet) and the second beyond B3.

1. <u>To B3</u>:

a. Observed gravity values have been reduced to Bouguer anomalies, using for the Bouguer correction a density of 2.65 gm/cm^3 (d_R) on Clark Island and 0.89 (d_I) on the ice sheet. The Bouguer anomalies on Clark Island have been plotted in Fig. 20. It will be seen on this figure that, apart from a 0.3 milligal deficiency at C8, the Bouguer gradient through the six stations on Clark Island is quite regular, and this encourages faith in the accuracy of the survey.

b. This Bouguer gradient on Clark Island has been extrapolated beneath the ice sheet as far as B3. There can, of course, be no proof that the mapped gradient continues under the ice sheet, but the gradient is compatible with the measured trend of rock density (see "<u>Line 9</u>" below) and with the probable isostatic situation hereabouts (see 2 below), and both these factors encourage its extrapolation.

c. At stations on the ice sheet the difference between the anomalies calcualted under (a) and those extrapolated under (b) should be proportional to the elevation of the ice base above or below sea level. The actual relationship between the differences (in milligals) and the elevations (in meters) has been derived from the standard formula for the attraction of an infinite slab, and is given by the expression $1/[2\pi G\ (d_R - d_I)]$, from which one milligal of difference equals 13.6 m of ice thickness.

This completes the account of the procedure to B3. Future workers may note that a Bouguer map of this whole area could be compiled very rapidly, without any survey problems, by establishing gravity stations at Haupt Nunatak (summit elevation 85 m) and at sea level points throughout the Windmill Islands and on the Balaena, Frazier and Hatch Islands. With the aid of this, fairly accurate ice thickness determinations of the whole margin of the ice sheet could be made by gravity, using altimetry (carefully applied and avoiding the pressure jump danger mentioned in Section II-B-15) for elevation control.

2. Beyond B3:

Obviously the Bouguer gradient of Clark Island cannot be extrapolated indefinitely. The limit of B3 for the application of the extrapolation has been chosen: (a) for the purely glaciological reason that B3 is the station nearest to the upper boundary of the superimposed ice zone which was an object of special study in 1958, and (b) for isostatic reasons discussed below. Beyond B3 the method of allowing for density and isostatic changes needs to be reconsidered. Concerning changes in density, however, there is in fact no method above B3 by which such changes can be distinguished from those of ice thickness. This fact places a fundamental limitation on the accuracy of the survey. As regards its probable accuracy, however, although in parts of the Canadian Shield density changes are known to produce Bouguer anomaly changes of 37 milligals per kilometer, such changes are nevertheless exceptional, and throughout the world as a whole anomalies do not usually change by more than a few tens of milligals over a distance such as the 66 kilometers here involved. Obviously, however, a seismic or other check would be desirable at the inner end of the traverse. Concerning isostatic corrections, these are required because the increasingly high mass of the ice sheet must be compensated for at depth by material of low density. This, of course, is the reason for the negative Bouguer anomalies of high continental areas, and disregard of it here would give ice thickness results that would be too large. The actual correction employed depends on what particular assumptions are to be made concerning the method and amount of compensation. In the case of this survey it has been assumed; (a) that above B3 the ice thickness changes slowly and evenly enough for compensation to be achieved, (b) that the area under consideration is uniformly affected by any glacially controlled sinking or rebound of the crust , and (c) that free air anomalies provide an approximate indication of isostatic compensation. On these assumptions, variations in the free-air anomaly as compared with that at B3 should indicate changes in the elevation of the ice base relative to its elevation at that point. The amount of change is given by the original formula (1 milligal = 13.6 meters). The use of this method saves the arithmetic of calculating Bouguer anomalies above B3. The method is not suitable for use below B3 (a) because it takes no account of density variations, which can however be allowed for by the method of extrapolated anomalies and (b) because free air anomalies can be expected to decrease sharply as the ice steepens at its edge, not because the elevation of the ice base is changing but because the rigidity of the crust prohibits perfect compensation. This topographic effect on free air anomalies is well known.

The values of the gravity survey are listed in the table at the end of this section. Note the following:

Line 1. Stations A2 and B9 are the same (S-1). The small discrepancy in values is probably the result of (a) instrument drift and (b) a different configuration of the snow surface on the second visit.

Line 2. Elevations have been taken from the table in Section II-C-2.

Lines 3 and 4. Meter dial divisions differ from milligals by a varying factor of approximately 0.75%. They have been corrected using a meter calibration supplied by the University of Wisconsin Antarctic Research Center. The milligal values thus obtained have been adjusted to absolute gravity values using the base value for Wilkes Station quoted in the report by E. Thiel mentioned above.

Line 6. Theoretical gravity values from the International Formula have been taken from Lambert and Darling's tables in the Bulletin Géodésique V. 32, 1931.

Line 8. Although the rock exposures of Clark and Bailey Island are rugged (on a small scale) their total relief is not great, and the most significant topographic feature in the area of the survey is the 4-5° slope, less than 1.6 km long, of the Ramp. Terrain corrections are therefore small. However, they were worked out during 1958, using tables by Hammer available at the Base. Corrections out to the limit of Hammer's Zone K (9.9 km radius) were calculated from such topographical information as was available, using densities of 0.9 for ice, 1.0 for sea-water, and 2.65 for rock, and assuming that the ice base was everywhere at the height of C5. More distant features have been ignored since any slight effect they may have will tend to apply equally over the whole area of the survey. Terrain corrections have not been applied above B3, since their possible magnitude is negligible compared with other inaccuracies of the survey.

Line 9. Bouguer corrections have been calcualted using an average density of 2.65 for the rock hereabouts. The densities of three typical rock specimens from the neighborhood of each of the gravity stations on Clark Island were determined at Wilkes Station, with the following results:

Base:	Pegmatite	2.62	pegmatite	2.62	gneiss	2.69	average	2.64
C9 :	Granite	2.56	gneiss	2.73	gneiss	2.82	average	2.70
C8 :	Granite	2.60	granite-gneiss	2.66	gneiss	2.72	average	2.66
C7 :	Granite	2.61	gneiss	2.64	gneiss	2.66	average	2.64
C6 :	Granite	2.57	granite	2.58	gneiss	2.74	average	2.63
C5 :	Granite	2.57	pegmatite	2.59	gneiss	2.65	average	2.60

Line 11. As explained, this gives the Bouguer anomaly extrapolated with the aid of Fig. 20.

Errors. Because the ice sheet is a relatively large feature, and because the density contrast between it and the rock below is so great, it is clear that a useful gravity survey of ice thickness can be made with much less attention to precision than is required by normal geophysical work. For example, errors of one milligal in gravity and one meter in elevation produce errors in ice thickness of only 13.6 meters and 2.7 meters respectively. This particular survey may include errors in elevation of up to three meters at B3 and 15 meters at A9, errors in the terrain correction of up to 0.2 milligals, and errors of drift (not allowed for, but less than 0.3 milligals with this meter in this latitude). These add up to a total error equivalent to 15 meters of ice at B3, and 47 meters of ice at A9. These figures are small in comparison with the errors which might be produced by isostatic and density anomalies beneath the ice sheet.

Note that the ice thicknesses obtained by a gravity survey are "average thicknesses over a distance round the station comparable with the local ice thickness" (Masson-Smith, in preparation) so that the profile in Fig. 21 may represent a somewhat smoothed picture of the subglacial topography. Note also that the effect of englacial debris in the area of the Ramp will be to make the calcualted ice thickness there somewhat less than the actual.

Results. The ice thickness values obtained by the survey have been plotted in the two profiles (Figs. 21 and 22) at the end of this section. The question marks in Fig. 22 have been used to emphasize the speculative nature of the values for the inland stations. In spite of the smoothing effect mentioned in the last paragraph, and although this survey represents only one line profile, the thickness values as far as B3 suggest that the subglacial surface to that point has the same small relief as Clark and Bailey Islands. This conclusion fits well with the striking regularity of the ice sheet surface hereabouts, well illustrated by the steady decrease of the angles in line 19 of the table at the end of this section. Beyond B3, in spite of the possible inaccuracies of the survey, the calculated subglacial topography correlates well with the ice surface topography. For example, the apparent depression below A9 is probably related to a well-marked (in the field) temporary decrease in the surface slope at that point. Further discussion of the absolute values of ice thickness beyond B3 is included in the following section on the basal shear stress.

Some other geophysical observations in the Wilkes Station area may be mentioned here. During the summer of 1958, an ice thickness measurement of 152 meters was made by A. Waite (U. S. Army Signal Corps), using an experimental radio-sounding technique at a point which was unfortunately not marked, but was probably station A1 (gravity thickness 132 meters). In December 1959, a gravity measurement at B9 (S-1) was made by E. Thiel, who landed there after a flight from McMurdo Sound. His measurement was made at the base of the S-1 weather mast at an elevation here estimated to be within 1 m of that of B9. His value of 982.3331 gals is 0.5 mgals greater than the average of the two 1958 values. This hardly significant increase may be partly accounted for by the downward movement of the ice sheet. Gravity measurements in the Windmill Islands have also been made by the Australian National Antarctic Research Expedition, but have not yet been reduced to absolute values.

The author thanks H. Birkenhauer, S.J., and Dr. C. R. Bentley for their help in various aspects of this survey.

Additional note. In a paper just published, Evison, et al. (1960) speculate on the possibility of an extension of the oceanic crust southwest of Wilkes Station. In this connection, note (a) the positive Bouguer anomaly at the station, and (b) the relatively low elevations (approximately 750 m) recorded in the area of the 1958 traverse (Fig. 1). Future investigators may care to check further the possible relationship between these phenomena.

B. THE SHEAR STRESS AT THE ICE BASE
(Hollin)

The apparent smoothness of the ice base in this area makes the thickness values obtained particularly suitable for consideration in the context of Nye's (1952) equation relating the thickness and surface slope of an ice sheet to the shear stress at its base. In this equation $T = dgh \sin A$ where

T = the shear stress at the base
d = the density of the ice
g = the acceleration due to gravity
h = the thickness of the ice, and
A = the maximum slope at the point under consideration.

Let "d" be 0.89 gm/cm^3: less than the density of pure ice in order to allow for the low density of the upper layers of the ice sheet. 982 gals is a sufficiently accurate value of "g".

Values of "h" are listed in line 16 of the table at the end of this section. The least well-known factor in the equation is "A", which was measured at only a few of the gravity stations. The angle at the remaining stations has been calculated as follows.

Firstly, the vertical angle of the S-2 trail has been calculated. Secondly, the horizontal angle between the line of the trail and the line of maximum slope has been calculated. Thirdly, the tangent of the vertical angle of the trail has been divided by the cosine of the horizontal angle above to give the tangent of the vertical angle of the line of maximum slope. This last operation is justified by the general regularity of the ice sheet surface in this area. The procedure followed in each of these steps is outlined below, but first the few actual measurements available are tabulated.

a. Approximate data from S-2, calculated from the January 1959 data of Movement survey III-H.

Azimuth (true) of the trail (from Topographic survey II-B-10)	106°
Surface angle of the trail	35'
Azimuth (true) of the line of maximum slope	90°
Maximum surface slope	40'

b. Data obtained with a transit at four positions on 4 February 1959. Azimuths have been obtained by assuming a magnetic variation of 85°, and are therefore $\pm 5\text{-}1/4^\circ$ (see Section II-B-12).

i Point	ii Local time (hrs)	iii Angle of Maximum Upward Slope	iv Azimuth of Maximum Upward Slope	v Angle of Maximum Downward Slope	vi Azimuth of Maximum Downward Slope	vii Azimuth of Trail (Upward)	viii Azimuth of Trail (Downward)	ix Remarks
A3	1635	56'	95°	$1^\circ 06'$	259°	110°	297°	Angles stay within one minute of the maximum for approximately 20° sectors of the upward and downward horizons.
B3	1705	$1^\circ 17'$	106°	$1^\circ 29'$	277°	120°	300°	
B7	1720	$1^\circ 31'$	99°	$1^\circ 48'$	280°	89°	270°	
B9	1735	$1^\circ 45'$	112°	$2^\circ 02'$	284°	95°	271°	Trail angle $1^\circ 41'$ upward and $2^\circ 1'$ downward.

Reverting to the three steps outlined above:

1. All the on-ice stations of the gravity survey lie on the S-2 trail. (Below B14 at the shear moraine the trail is considered for this purpose to run down through C2, C3, and C4 to C5.) The tangent of the surface angle of the trail at each station has been calculated by dividing the elevation difference between nearby points at roughly equal distances uphill and downhill from the station by the distance between these points. Elevations have been taken from Section II-C-2 and distances from Fig. 11 (Northern Area map) and Section II-B-10. Because the ice sheet has a generally parabolic profile this method may give angles which are a few minutes too high.

2a. The azimuth of the trail has been taken from Fig. 11 and Section II-B-10. The azimuths so obtained agree with lines vii and viii of table b within the limits of accuracy of that table, as shown below:

Position	A3	B3	B7	B9
Azimuth of trail by Fig. 11 and Section II-B-10	114°	124	90	96
Azimuth of trail as an average of lines vii and viii (-180°)	114	120	90	93

b. The azimuth of the line of maximum slope has been estimated from Fig. 11, Section II-B-10, and from knowledge of the area. The estimates so obtained have been adjusted to the actual measurements in tables a. and b. (lines iv and vi).

3. The final calculated vertical angles of the line of maximum slope are compared below with the actual measurements (average of lines iii and v of the table above) of that value.

Position	S-2	A3	B3	B7	B9
Calculated angle	32'	$1^{\circ}6'$	$1^{\circ}26'$	$1^{\circ}41'$	$1^{\circ}54'$
Measured angle	40'	$1^{\circ}1'$	$1^{\circ}23'$	$1^{\circ}40'$	$1^{\circ}53'$

The measured angles above are the average of sights from instrument height to the highest and lowest horizon visible, and because the ice sheet has a generally parabolic profile this method may give angles which are a few minutes too low. For the stations above, the measured angles have been listed in line 19 of the table at the end of this section; for the other stations the calculated angles have been listed. The calculated angles at stations A4 to A9 are based on limited data (Section II-B-10) and may be considerable in error.

Results

The calculated values of T for each station are listed in line 20 of the table at the end of this section. If the assumptions of the gravity survey are correct (and certainty on this point can only come from a check by seismic or other means) then the maximum possible error in T due to uncertainties in the thickness "h" and the angle "A" is 0.05 bars at B3. Downhill from B3 the error is less than this and uphill more. The results are discussed briefly below, in the light of a recent paper by Nye (1959), and of the references at the end of that paper.

Theoretically T should vary with the velocity and basal temperature of a "cold" ice sheet and with the roughness of its bed. Concerning roughness, little is known about this theoretically, and in practice general geological considerations (in particular the petrology of the shear moraine erratics) suggest that the roughness is quite likely to be constant over the area considered. Concerning the basal temperature, for the (relatively thin) Ramp this is almost certainly below the melting point, and indeed no streams were ever observed issuing from beneath the ice. But above the shear moraine it is possible that the thickness of the ice is sufficient to allow the geothermal heat flow (on a worldwide average able to maintain a gradient in ice of $1^{o}C/54$ m) to raise the basal temperature to the melting point. However, this is only a possibility, and the possible range of geothermal heat flow values is so great that the further consideration of other factors such as air temperature, the advection of ice and frictional heating is not worthwhile. Temperature, therefore, remains an unknown in this consideration of the value of T. Concerning movement, this was measured (Movement survey III-F) and found to be approximately 2 m/yr just above the shear moraine. From the topography of the ice sheet, and from the pattern of accumulation and ablation on it, it seems likely that this velocity increases fairly steadily all the way to Mile 40 (km 66). At Mile 40 (km 66) mass budget calculations suggest that the movement is of the order of 10 m/yr. Using these general facts concerning roughness, temperature and velocity, we can treat the value of T in three sections:

1. The low values of 0.33 and 0.37 bars for C4 and C3 come from the lower part of the Ramp. The data from other glaciers suggest that appreciable movement is hardly likely at such low stress, particularly at the low temperatures which apply here. In fact, the data of Movement survey III-G show that the movement for a year, not far from C4, was too small to be measured. These findings illuminate the role of the Ramp as an inactive ice barrier to the active ice above the shear moraine.

2. For the twelve stations between C2 and B3, T varies only between 0.56 and 0.71 bars. This is the smallest spread of basal shear stresses known to the author, and the probable reasons for it are of great interest:

a. The relative smoothness of the ice base here is confirmed by the very striking smoothness of the ice surface. However, the previously mentioned thickness-averaging effect of the gravity survey may have masked some minor variations of h and therefore of T.

b. It was noted above that the velocity of the ice between C2 and B3 is not constant; it probably varies by a factor of approximately two. That this variation is unaccompanied by any significant variation in the value of T is an argument for the dependence of the velocity or strain or a high power of T or stress. Such a dependence agrees with the laboratory results of Glen, whose flow law for ice is referred to by Nye in his paper above.

c. Since such variations of velocity as exist on the trail are unlikely to be exactly balanced by variations of basal temperature, the constancy of T argues, admittedly slightly, for a constant basal temperature. Whether or not this is constant at the melting point is, or course, unknown. However, it is interesting to note that the ice base in a similar situation 5 km inland from the Russian base at Mirny was probably at the melting point (Bogoslovski, 1958). The possibility that the wide Ramp and the shear moraine at Wilkes are produced by the transition from a "warm" ice base to marginal "cold" ice base will be examined in a later publication.

3. It has been emphasized that the ice thickness figures above B3 are rather speculative. However, the fact that the values of T remain in the same range as far as A6 suggests that the figures are not too far in error, at least in relation to each other. The slight rise in T beyond A6 may be due to (a) decreased basal ice temperatures, or (b) a greater ice velocity in the direction of the Peterson Glacier, or (c) an overestimate of the ice thickness or surface angle. The latter is the most likely explanation, and obviously there is a need (particularly at S-1, Mile 20 (km 33.5), Mile 40 (km 66), and S-2) for seismic soundings at some inland locations.

GRAVITY SURVEY TABLE

1.	Station	Base	C9	C8	C7	C6
2.	Elevation (meters)	10.9	14	20	44	51
3.	Dial reading	4944.902	4943.897	4942.199	4937.347	4935.868
4.	Observed gravity, mgals. 982,000+	399.60	398.59	396.88	391.99	390.50
5.	+ Free-air correction	3.4	4.2	.6.1	13.6	15.8
6.	- Theoretical gravity, mgals. 982,000+	379.6	379.8	379.9	380.3	380.5
7.	= Free-air anomaly	23.4	23.0	23.1	25.3	25.8
8.	+ Terrain correction	0.3	0.3	0.2	0.2	0.3
9.	- Bouguer correction (d = 2.65 to C5; 0.89 beyond)	1.2	1.5	2.2	4.9	5.7
10.	= Bouguer anomaly	22.5	21.8	21.1	20.6	20.4
11.	- Extrapolated periglacial anomaly					
12.	= Anomaly due to ice-rock difference					
13.	x 13.6 = elevation of ice base in meters (this method to B3)					
14.	Variation in free-air anomaly from that at B3					
15.	x 13.6 = elevation of ice base relative to B3 (this method beyond B3)					
16.	Ice thickness in meters					
17.	Azimuth (°true) of trail					
18.	Azimuth (°true) of maximum slope					
19.	Calculated maximum slope					
20.	Shear stress at the ice base (bars)					

GRAVITY SURVEY TABLE (Contd.)

1.	C5	C4	C3	C2	B14	C1	A1	B13	B12	B11
2.	45.1	52	108	131	142	161	170	175	198	226
3.	4937.606	4933.546	4921.233	4915.573	4910.671	4905.513	4902.924	4900.911	4895.652	4887.530
4.	392.25	388.16	375.75	368.03	365.11	359.91	357.30	355.28	349.99	341.80
5.	13.9	15.9	33.2	40.4	44.0	49.7	52.3	54.0	61.2	69.9
6.	381.3	381.3	381.3	381.3	381.3	381.3	381.3	381.3	381.3	381.4
7.	24.8	22.8	27.6	27.1	27.8	28.3	28.3	28.0	29.9	30.3
8.	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
9.	5.0	1.9	4.0	4.9	5.3	6.0	6.3	6.5	7.4	8.4
10.	20.2	21.1	23.8	22.4	22.7	22.5	22.2	21.7	22.7	22.1
11.		20.1	19.8	19.6	19.6	19.4	19.4	19.3	19.0	18.7
12.		1.0	4.0	2.8	3.1	3.1	2.8	2.4	3.7	3.4
13.		14	54	38	42	42	38	33	50	46
14.										
15.										
16.		38	53	93	100	119	132	143	148	180
17.		88	88	90	111	100	90	95	92	93
18.		110	105	90	115	110	95	95	98	102
19.		5°20'	4°33'	4°47'	4°14'	3°53'	2°56'	2°37'	2°28'	2°09'
20.		0.33	0.37	0.68	0.66	0.71	0.60	0.58	0.56	0.60

GRAVITY SURVEY TABLE (Contd.)

1.	B10	B9(S-1)	A2(S-1)	B8	B7	B6	B5	B4	B3	B2
2.	245	262	262	281	302	322			365	
3.	4882.492	4878.261	4878.473	4872.188	4866.104	4860.339	4855.292	4852.653	4850.033	4847.292
4.	336.72	332.46	332.67	326.34	320.21	314.40	309.32	306.66	304.02	301.25
5.	75.7	80.8		87.0	93.3	99.0			113.0	
6.	381.4	381.4		381.5	381.5	381.5			381.9	
7.	31.0	31.9		31.8	32.0	31.9			35.12	
8.	0.2	0.2		0.1	0.1	0.1			0.1	
9.	9.1	9.7		10.5	11.2	12.0			13.6	
10.	22.1	22.4		21.4	20.9	20.0			21.6	
11.	18.4	18.1		17.8	17.5	17.2			16.1	
12.	3.7	4.3		3.6	3.4	2.8			5.5	
13.	50	59		49	46	38			75	
14.									0.0	
15.										
16.	195	203		233	256	284			291	
17.	94	96		93	90	97			124	
18.	105	108		104	100	103			112	
19.	$2^\circ 00'$	$1^\circ 54'$		$1^\circ 52'$	$1^\circ 41'$	$1^\circ 28'$			$1^\circ 26'$	
20.	0.62	0.60		0.67	0.67	0.64			0.64	

GRAVITY SURVEY TABLE (Contd.)

1.	B1	A3	A4	A5	A6	A7	A8	A9
2.		467	574	673	772	861	944	1016
3.	4844.371	4822.265	4791.823	4763.253	4736.608	4710.925	4681.677	4648.891
4.	298.31	276.05	245.37	216.58	189.75	163.87	134.39	101.36
5.		144.0	177.5	207.5	238.0	266.0	291.0	313.0
6.		383.2	385.2	387.0	388.0	390.0	392.0	393.5
7.		36.8	37.7	37.1	39.7	39.8	33.4	20.9
8.								
9.								
10.								
11.								
12.								
13.		98	110	102	137	138	51	-118
14.		+1.7	+2.6	+2.0	+4.6	+4.7	-1.7	-14.2
15.		+23	+35	+27	+62	+64	-23	-193
16.		369	465	571	635	723	893	1134
17.		114	114	114	101	114	106	106
18.		87	87	87	87	87	87	80
19.		1°06'	59'	41'	42'	41'	33'	28'
20.		0.62	0.70	0.59	0.67	0.74	0.75	0.80

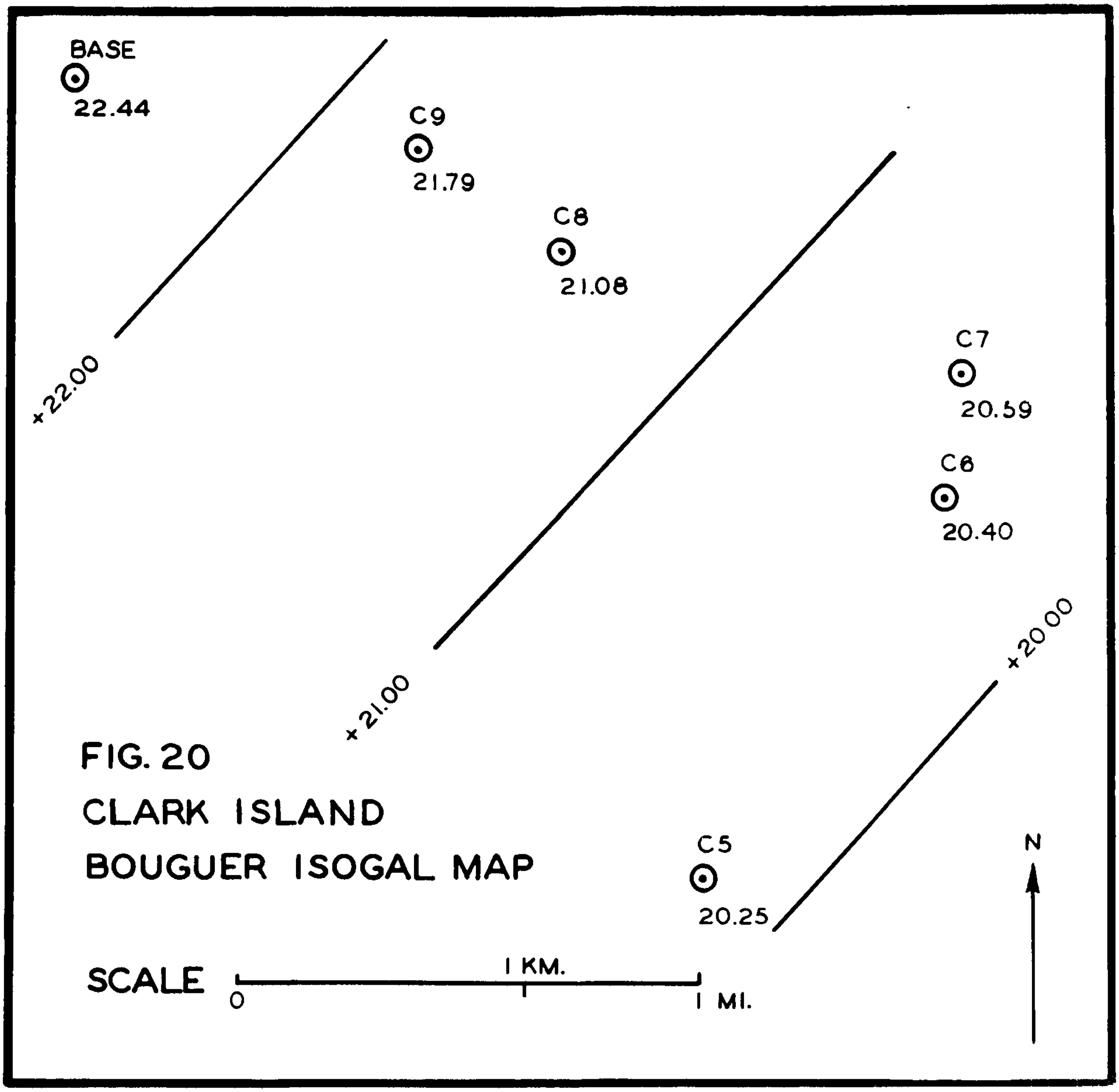


FIG. 20
CLARK ISLAND
BOUGUER ISOGAL MAP

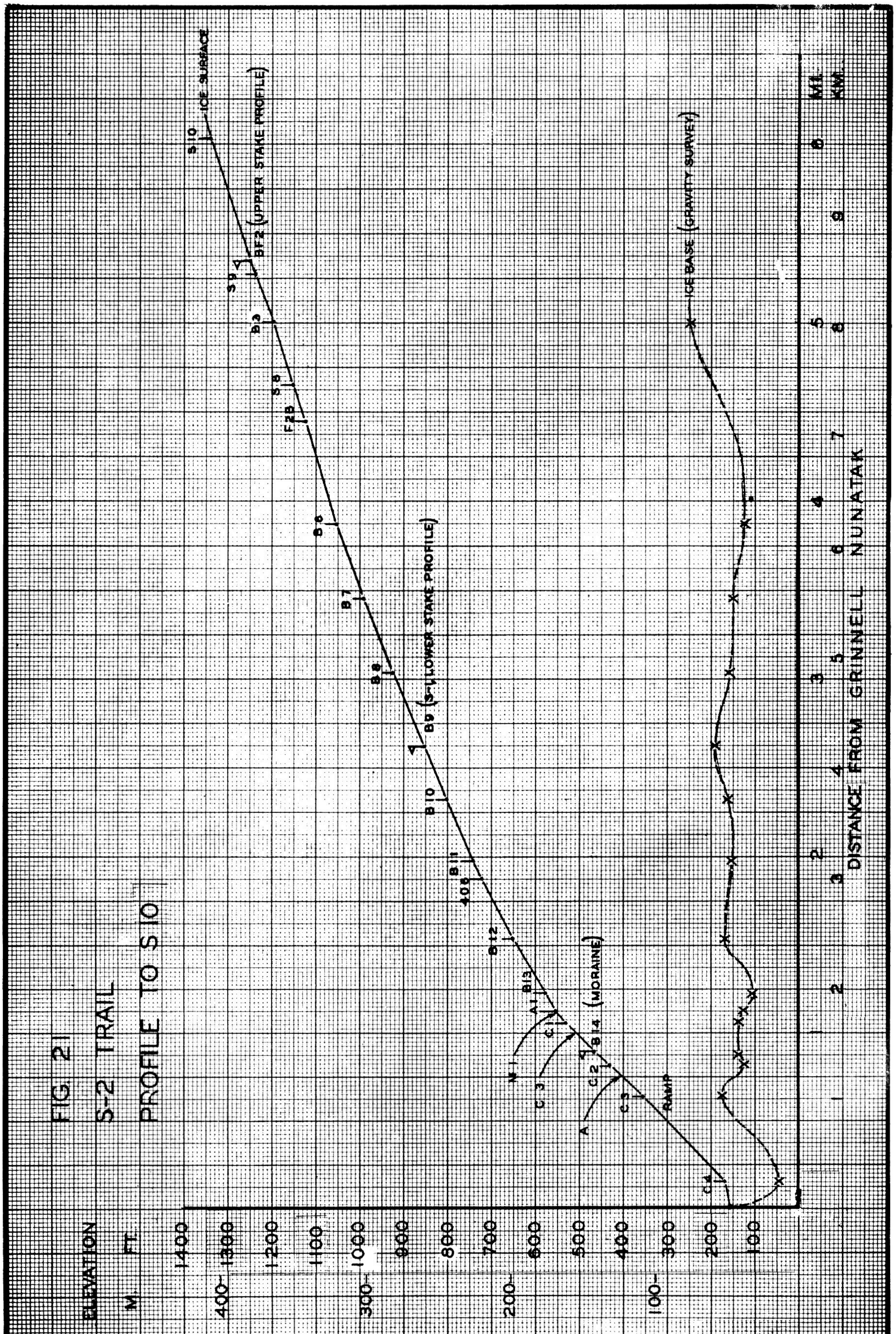


FIG. 21
S-2 TRAIL
PROFILE TO S 10
ELEVATION
M.
FT.
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
400
300
200
100
ICE SURFACE
BF2 (UPPER STAKE PROFILE)
B9 (S-1 LOWER STAKE PROFILE)
B14 (MORAINE)
RAMP
ICE BASE (GRAVITY SURVEY)
DISTANCE FROM GRINNELL NUNATAK
MI.
KM.

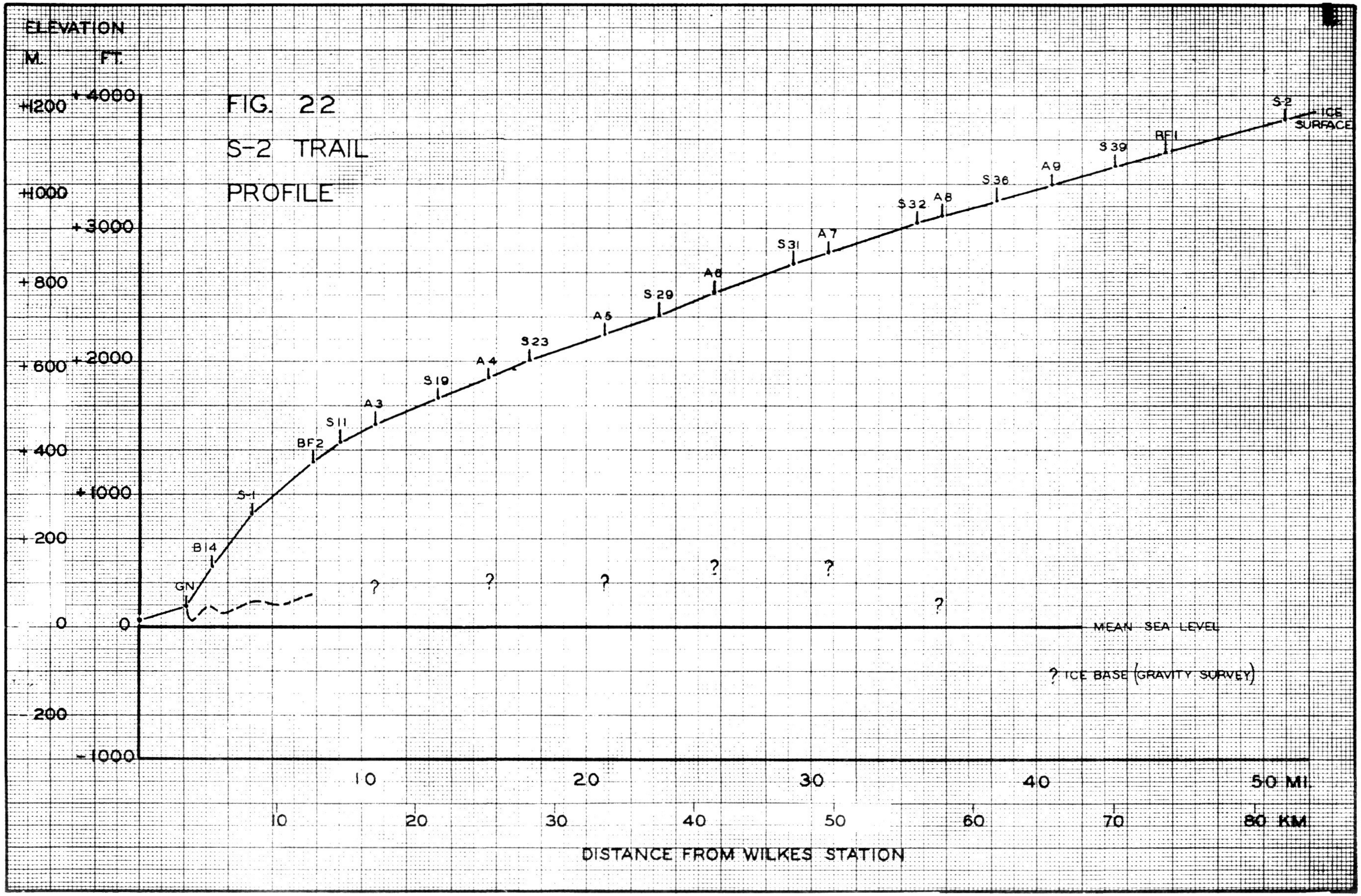


FIG. 22
S-2 TRAIL
PROFILE

V. METEOROLOGICAL AND OCEANOGRAPHICAL DATA

A. S-1

1. Weather (Hollin and Cronk)

The weather at S-1 reflected its intermediate position between Base and S-2. Apart from the obvious difference in temperature, the biggest difference between Base and S-2 was in the wind at each place. At Base the weather was usually calm (the mean wind speed of 18 km/hr in 1957 was the lowest at any East Antarctic station), but this calm was interrupted by occasional storms, and gusts of at least 95 km/hr were experienced during every month between March, 1957, and December, 1958. The strongest storm winds usually came from the NE. S-2 was normally quite windy (the mean wind speed there in 1957 was 40 km/hr), but did not experience such extreme winds as the Base.

At S-1 the wind was stronger and more presistent than at Base, but not so much so as at S-2. The predominant winds came from the E and SE, and were probably katabatic. They frequently carried blowing snow. Their persistence is illustrated by the almost complete absence of dirt on the ice sheet, above and to the east of the dirt-carrying shear planes. Calm days in the Wilkes area were often marked in winter by low stratus over the ice sheet and in summer by cumuliform clouds over the islands.

The notes below on the weather at S-1 were made quite incidentally during the weekly stake measurements (usually about noon) on the lower ice sheet, but may be of use in any further assessment of the meteorological differences between Base, S-1, and S-2.

31 July	No wind. Stratus (base 200 m) extends out to sea for 15 km.
24 Nov.	Sun shining through scattered low cloud cover which increases inland and decreases out to sea. Upper cloud cover is complete to S and SE.
8 Dec.	Overcast at both Base and S-1. Blowing snow at S-1.
15 Dec.	Clear sky at both Base and S-1.
22 Dec.	Overcast at both Base and S-1. Partial whiteout from 411 inland, but blue sky sometimes visible on SE horizon.
29 Dec.	Clear sky at both Base and S-1. Scattered clouds out to sea.
26 Jan.	Broken cloud at both Base and S-1.

2. Wind velocity (Cronk)

In December, 1958, the totalizing anemometer originally used at S-2 became available for use at S-1. Several days were needed to improve the performances of this instrument and the Base instrument to a point where the two gave almost identical and correct readings when exposed in the same situation for the same period. Finally, after cleaning and lubrication, the following check figures were achieved during runs at Base:

Period	Mileage of Base Instrument	Mileage of Glaciologist's Instru
29 Dec. - 2 Jan.	430.4	428.0
2 Jan. - 3 Jan.	130.2	132.0
3 Feb. - 4 Feb.	208.6	214.9

The February check was made by bringing the instrument back to Base shortly before the relief ship sailed.

The new instrument was installed at a height of seven meters (the same height as the Base instrument) above the surface at S-1. It was mounted on a duralumin mast twenty or thirty meters north of the thermograph screen. Readings at S-1 were taken whenever personnel happened to be in that area. The measurements obtained are tabulated below and compared with the readings at Base. The comparison affords objective support for the impression that the wind at S-1 was generally stronger than that below the shear moraine. The effect of this phenomenon on the distribution of blowing snow is illustrated by Fig. 40 of the Report for 1957.

Date	Time Obs.	Time since last Obs. (hrs)	S-1 Reading	S-1 Mileage	Base Mileage	S-1 Average		Base Average	
						mph	km/hr	mph	km/hr
3 Jan.	1613		7939						
6 Jan.	1400	69.8	100	2161	1506	30.9	49.7	21.6	34.7
10 Jan.	2316	105.3	1066	966	663	9.2	14.8	6.3	10.2
13 Jan.	1215	61.0	1760	694	446	11.4	18.4	7.3	11.8
20 Jan.	1437	170.4	2926	1166	768	6.8	10.9	4.5	7.2
25 Jan.	1610	121.6	4141	1215	990	10.0	16.1	8.1	13.0
26 Jan.	1100	18.8	4215	74	76	3.9	6.6	4.0	6.4
30 Jan.	1725	102.4	5324	1109	741	10.8	17.4	7.2	11.6
31 Jan.	1447	21.4	5435	111	110	5.2	8.4	5.1	8.2
2 Feb.	1630	49.4	5889	454	*	9.2	14.8	*	

*Not available

3. Air temperatures (Cronk)

The installation of the thermograph shelter at S-1 is described in the Report for 1957. Probably the 1957-58 melt caused it to sink considerably. However, the installation remained firm and it was considered unnecessary in 1958 to break the records by raising the shelter. On

17 February 1958, the base of the shelter was 65 cm above the surrounding general level and on 17 January 1959, 40 cm above it. In general the surrounding surface was bare ice until July, 1958, and snow covered after that. A more precise record of the surface can be obtained from the weekly measurements at Stake 410, which stood approximately 5 m east of the thermograph. Immediately beneath the shelter a shallow scoop, probably the result of wind and radiation, kept the local surface approximately 20 cm below the surrounding general level. The thermograph element inside stood approximately 20 cm above the base of the shelter; i.e., on 17 February 1958, a total of 1.05 m above the ground.

The thermograph used was a standard U. S. Weather Bureau instrument. The graph was normally changed at approximately noon each Monday by a glaciologist or voluntary worker. The change was occasionally delayed by bad weather which prohibited the 8 km journey from Base. Blowing snow, which normally accompanied bad weather, was responsible for most of the instrument failure recorded, either stopping the clock or blocking the movement of the pen arm. The shelter could normally be visited only once per week, and if failure occurred early in the record then inevitably several days were lost. However, usable records were obtained for 83 per cent of the time. The other 17 per cent, marked by blanks in the data, usually represents either the lack of any record at all, because of a stopped clock or snow-blurred trace, or records obtained but unusable because of excessive damping by clogging snow or jerking of the pen by winds (at Base every month included a wind of at least 95 km/hr).

The records which follow are presented by weeks. Each week's record is accompanied by remarks concerning the accuracy of the observations. It would have been normal practice to incorporate these remarks into "corrected" temperature figures. However, since these records may be used for quite detailed studies the figures recorded are taken directly from the thermograph trace. The remarks, therefore, should enable future workers both to apply their own corrections to the readings and to gauge their individual accuracy. Remarks apply to the period of the trace concerned. Sometimes this ran into a following week if bad weather delayed the change, but this can always be checked by reference to the data. The data contains errors of time and temperature and these are discussed below.

Errors of time

When the graph was changed the observer noted on it the time. This time is presented with each week's data as "OT" (Observer's time). Occasionally the observer had trouble with his watch and OT is then recorded as ± 30 minutes. Due usually to play in the drum mechanism, the OT at the beginning of the record does not always coincide with the time found on the thermograph trace. Time shown on the thermograph trace is noted as "TT". Normally the clock kept good time; however, any discrepancy at the end of the week is again recorded in terms of OT and TT. Sometimes the pen has obviously run into the brass bar holding down the graph paper and the record could have ended at any point in the four hour interval covered by the bar. "1330 AB" (1330 at bar) means that TT could be anything between 1330 and 1730 hours.

Errors of temperature

The temperature reading on the thermograph was checked each week by reference to a glass bulb thermometer mounted in the shelter. During the year the following thermometers were used for checking purposes:

	Date Installed	Date Replaced	Remarks
Wexler United States Weather Bureau Mercury (correction card checked)	25 Feb. 1957	2 June 1958	Broke in case
Wexler United States Weather Bureau Alcohol (correction card checked)	2 June 1958	29 Sept. 1958	Found 2^{o}F to 3^{o} high by voluntary workers while glaciologist away
Wexler United States Weather Bureau Alcohol (correction card checked)	29 Sept. 1958		

With each week's data the thermometer temperature at the time of changing the record is listed as "MT" and the thermograph temperature as "GT". Discrepancies between MT and GT at the beginning of the record are probably due to a lag in the adjustment of the thermograph to the shelter temperature after being changed outside the shelter. In these cases the pen has not been set correctly and a correction from GT and MT needs to be applied to the whole trace. Discrepancies at the end of a record are probably due to the damping and delaying effect on the instrument of a light wooden box, open at the downwind side, which covered the instrument (but not the thermometer) inside the shelter. This box protected the instrument against blowing snow and was necessary in order to obtain any appreciable quantity of records in this situation.

In addition to the above discrepancies between thermometer and thermograph temperatures the traces obtained include three other types of error due to bad weather and blowing snow. First, as blowing snow filled the shelter it obviously damped the trace, either by physically impeding the movement of the arm (long periods of identical temperature) or, more probably, by a thermal blanketing effect (gentle fluctuations of the curve). Wherever damping appears to have occurred this is noted in the records. However, many of the overcast days of winter probably gave a smooth trace in any case, and a comparison with the record at Wilkes Base should be made before damping is definitely assumed. It should be noted that the intense blowing snow which often stopped the instrument was probably often associated with warm air masses and, again, comparison with Base records would suggest any corrections needed when averaging. Secondly, a cooling effect must have been produced by the sublimation of blown snow from the bimetallic strip in particular. Periods when this occurred were, however, probably few and associated with imminent complete failure of the instrument. Thirdly, if snow reached the pen a fuzzing of the trace occurred and this is recorded when necessary in the data. Sometimes when the clock stopped late in the week, but the pen continued to move (making a vertical line only on the trac) it has been possible to suggest in the remarks a maximum and minimum temperature for the remainder of the week.

The above discussion emphasizes the difficulty of maintaining a conventional thermograph at a remote station. An ideal apparatus would include; first, a shelter which excluded or let completely through any blowing snow and second, a completely sealed recording system. The records below, presented for one hour and $1/10^{\circ}$ intervals, have been picked from traces marked at intervals of two hours and 1°. Temperatures are in degrees Fahrenheit, and positive unless preceded by a minus sign. With the corrections recorded it should be possible to produce final figures and averages with a calculable margin of error. Accurate analysis should be made with the help of the actual traces both for this station and for Wilkes Base.

Summary of Abbreviations

OT	Observer's time
TT	Thermograph time
MT	Thermometer temperature
GT	Thermograph temperature
AB	At bar
NR	Not recorded

S-1 AIR TEMPERATURES

Time	27/1	28/1	29/1	30/1	31/1	1/2	2/2	3/2	Remarks
0100		15.2	26.6	20.0	19.8	16.6	16.0	22.9	Start
0200		14.8	24.0	21.3	20.0	16.0	15.3	22.9	OT 1500/27
0300		18.6	23.0	22.4	20.2	16.9	15.6	22.8	TT 1500
0400		17.8	21.9	21.0	22.6	17.0	16.2	22.8	MT 25.2
0500		20.0	23.0	20.0	21.0	18.5	18.5	23.0	GT 24.6
0600		21.1	25.0	24.0	22.6	19.8	19.9	22.7	
0700		23.0	26.4	25.0	25.5	22.5	23.8	24.1	End
0800		25.2	27.9	26.0	28.7	25.1	22.8	24.0	OT 1240/3
0900		27.3	27.6	28.0	26.1	28.0	24.0	27.1	TT 1220
1000		27.0	27.9	28.7	30.0	29.3	23.3	26.7	MT 36.6
1100		31.4	27.8	29.2	31.5	29.5	24.0	28.1	GT 29.0
1200		31.2	27.9	28.5	32.7	29.9	25.6	28.0	
1300		32.5	27.8	28.0	30.8	32.0	24.3	29.0	
1400		34.7	27.8	29.1	30.7	30.0	24.5		
1500		33.0	27.9	29.1	31.8	28.8	24.5		
1600	24.6	31.5	27.6	28.7	35.0	32.1	24.3		
1700	24.0	30.8	27.0	26.0	30.0	30.0	24.2		
1800	23.7	31.7	26.3	27.8	27.9	27.0	23.7		
1900	23.2	30.8	25.2	25.0	25.3	27.5	22.4		
2000	21.5	29.8	23.9	22.3	23.5	23.0	22.5		
2100	18.0	26.5	23.0	23.4	21.5	20.7	22.7		
2200	16.5	26.7	21.1	23.8	19.8	19.2	23.2		
2300	17.5	27.0	19.2	24.0	19.0	18.1	22.0		
2400	15.8	26.5	20.8	22.7	16.7	17.0	22.4		

Time	3/2	4/2	5/2	6/2	7/2	8/2	9/2	10/2	Remarks
0100		24.2	23.8	14.8	26.3	23.5	20.1	21.5	Start
0200		24.1	23.9	14.3	26.5	23.1	19.5	21.0	OT 1241/3
0300		24.1	23.9	15.0	26.8	23.2	19.3	20.8	TT 1240
0400		24.4	24.0	21.4	26.4	23.4	20.1	20.5	MT 36.6
0500		24.9	24.5	24.0	26.2	24.8	20.2	20.5	GT 36.0
0600		25.2	25.2	25.0	27.0	26.1	21.9	20.4	
0700		25.5	27.0	26.0	27.3	27.0	22.9	20.6	End
0800		26.1	28.8	26.9	28.1	30.6	22.8	21.4	OT 1115/10
0900		26.9	27.4	26.9	28.9	35.0	22.9	22.3	TT 1100
1000		27.1	27.1	27.9	30.7	34.0	23.9	22.6	MT 24.0
1100		27.8	27.0	28.0	31.2	38.2	24.2	23.8	GT 23.8
1200		27.7	26.7	29.2	30.0	31.2	24.8		
1300	36.0	27.8	27.6	29.0	29.9	36.9	24.3		
1400	27.9	28.0	26.6	29.1	30.2	32.7	24.1		
1500	28.7	28.0	26.0	27.7	28.4	31.0	25.0		
1600	29.5	27.9	25.2	27.3	28.2	25.4	24.4		
1700	26.7	26.6	24.8	27.2	29.0	27.4	22.7		
1800	26.1	25.4	23.8	26.7	28.0	26.0	22.2		
1900	26.8	25.3	22.0	26.5	26.5	24.0	22.4		
2000	25.3	25.0	19.0	26.0	25.0	24.3	22.2		
2100	25.0	24.7	17.3	25.8	24.9	20.1	22.0		
2200	25.0	24.5	16.0	26.0	25.0	20.8	21.9		
2300	24.9	24.1	15.0	25.8	24.1	21.3	21.8		
2400	24.2	24.0	14.0	25.7	23.7	20.2	21.8		

S-1 AIR TEMPERATURES (Continued)

Time	10/2	11/2	12/2	13/2	14/2	15/2	16/2	17/2	Remarks
0100		24.3	21.4		17.3	19.0	18.6	14.4	Start
0200		24.1	22.3		20.0	18.4	19.0	13.0	OT 1115/10
0300		24.3	22.0		19.8	18.5	20.0	11.6	TT 1115
0400		24.8	22.0		19.0	21.6	20.1	12.0	MT 24.0
0500		24.9	23.1		19.8	21.6	20.5	12.0	GT 24.0
0600		25.0	23.2		19.9	27.1	21.1	13.0	
0700		25.4	26.0		21.2	28.4	21.0	14.6	End
0800		26.0	26.7		22.8	24.5	21.3	16.1	OT 1115/17
0900		26.4	23.2		24.5	25.7	21.4	18.1	TT 1110
1000		26.8	24.0		29.0	26.1	22.7	20.0	MT 20.5
1100		27.1	29.5		26.2	27.8	22.1	21.8	GT 21.8
1200	24.5	27.2			27.0	28.6	23.0		
1300	24.3	27.8			27.8	27.2	23.0		
1400	25.0	27.2			26.5	27.6	22.5		
1500	25.7	27.1			25.8	28.8	22.1		
1600	25.8	26.9			24.9	28.0	19.0		
1700	26.2	26.8			24.0	27.9	18.9		
1800	25.1	26.0			23.9	22.5	18.9		
1900	24.9	25.1			23.5	19.2	16.8		
2000	24.8	24.1			23.1	17.0	15.6		
2100	24.8	24.2			20.0	19.0	14.0		
2200	25.1	23.2		15.5	17.0	18.2	13.9		
2300	25.0	22.9		15.7	16.0	18.6	13.8		
2400	24.3	22.1		16.0	18.1	17.2	12.2		

Time	17/2	18/2	19/2	20/2	21/2	22/2	23/2	24/2	Remarks
0100		8.4	15.9	20.2	12.9	10.0	18.0	21.9	Start
0200		8.1	15.7	19.8	12.8	7.9	18.0	22.0	OT 1115/17
0300		7.7	15.7	19.0	12.7	7.3		21.0	TT 1145
0400		7.1	15.9	19.1	10.0	7.1		20.6	MT 20.5
0500		7.9	15.5	19.4	10.1	7.3		20.7	GT 21.0
0600		8.8	15.3	19.5	10.0	9.0		22.0	
0700		9.9	14.8	19.1	11.0	10.5		21.9	End
0800		11.0	14.8	19.0	12.4	14.5		22.9	OT 1415/24
0900		14.0	16.2	18.9	13.6	18.0		23.8	TT 1330 AB
1000		15.9	15.9	18.9	15.3	19.3		23.9	MT 26.4
1100		17.1	16.0	19.0	16.7	18.9		22.7	GT 23.9
1200	21.0	18.0	16.6	20.8	17.0	18.5		22.2	
1300	21.7	19.6	17.0	20.5	17.0	18.0		22.3	
1400	22.8	19.3	17.6	19.6	17.1	18.1			
1500	21.5	19.7	17.8	19.3	17.1	19.0			
1600	19.8	18.8	17.8	18.5	18.2	19.1			
1700	18.8	19.4	17.6	17.5	17.5	18.9	22.3		
1800	17.3	16.8	17.2	16.8	16.9	18.2	22.0		
1900	15.2	13.2	18.0	16.0	16.0	18.2	21.4		
2000	15.1	13.1	17.8	14.3	13.1	18.0	21.1		
2100	15.0	14.7	19.2	14.2	11.8	18.2	20.9		
2200	10.1	15.0	17.9	13.8	11.3	18.7	20.9		
2300	9.0	14.9	19.5	12.7	10.9	18.3	20.8		
2400	8.7	15.8	20.0	12.1	11.0	18.3	21.0		

S-1 AIR TEMPERATURES (Continued)

Time	24/2	25/2	26/2	27/2	28/2	1/3	2/3	3/3	Remarks
0100		18.6	12.1	16.0	14.9	9.0	5.1	16.5	Start
0200		18.1	12.2	16.1	15.0	9.6	8.6	13.9	OT 1415/24
0300		18.1	12.0	16.7	14.9	8.5	11.2	12.0	TT 1415
0400		18.2	11.0	16.8	14.0	10.4	12.1	9.5	MT 26.4
0500		18.2	10.6	16.9	13.3	9.0	12.8	11.0	GT 27.9
0600		18.9	12.3	16.9	11.7	10.1	13.1	12.2	
0700		19.2	13.7	16.6	12.0	13.0	13.6	14.0	End
0800		19.0	14.1	16.3	13.8	13.3	14.7	15.5	OT 1030/3
0900		17.7	16.0	16.6	14.2	14.2	15.0	19.0	TT 1010
1000		17.4	16.8	16.7	14.5	15.8	15.9	21.1	MT 21.75
1100		17.6	16.7	16.5	15.7	17.1	16.5		GT 21.3
1200		17.8	16.8	16.7	17.2	17.9	17.5		
1300		17.7	16.9	16.7	18.4	17.8	19.0		
1400		17.5	16.2	17.0	18.0	18.0	20.0		
1500	26.9	17.3	16.0	16.1	17.4	17.0	22.1		
1600	26.0	17.0	15.0	15.9	17.3	16.0	22.1		
1700	25.0	16.8	14.7	15.3	17.0	15.2	19.5		
1800	24.0	16.5	14.4	15.4	15.1	14.1	18.7		
1900	23.6	16.2	14.5	15.8	14.6	14.0	19.0		
2000	23.0	15.4	14.8	15.9	14.0	10.4	19.4		
2100	21.7	14.9	15.0	16.0	12.3	6.0	18.3		
2200	21.8	14.6	15.0	16.4	9.2	4.9	18.3		
2300	19.8	14.0	15.1	16.0	8.4	5.0	18.1		
2400	19.3	11.0	15.4	15.0	9.0	5.0	18.0		

Time	3/3	4/3	5/3	6/3	7/3	8/3	9/3	10/3	Remarks
0100		11.1	21.0	12.0	8.2	2.9	12.7	19.1	Start
0200		10.4	21.2	13.1	7.5	2.0	12.9	17.5	OT 1030/3
0300		10.3	21.5	12.0	7.0	1.6	13.0	13.7	TT 1045
0400		10.0	21.7	14.4	6.4	1.2	13.1	13.0	MT 21.75
0500		9.0	21.3	15.0	6.5	1.0	13.3	11.5	GT 24.0
0600		9.7	21.8	17.0	8.7	2.2	13.9	10.2	
0700		12.0	22.5	17.3	10.0	4.0	14.5	13.0	End
0800		14.5	26.2	18.1	12.0	6.0	14.9	15.0	OT 1315/10
0900		16.0	28.7	20.0	14.0	8.5	16.3	16.0	TT 1245
1000		18.3	29.0	22.1	17.2	11.1	17.8	19.2	MT 22.5
1100	24.0	22.0	32.1	25.7	22.5	14.0	18.2	19.1	GT 21.8
1200	23.2	23.1	32.2	25.1	23.0	15.2	17.0	19.8	
1300	24.5	22.4	31.5	25.1	24.0	16.1	16.5	21.8	
1400	24.0	22.8	31.1	24.5	22.8	17.0	17.3		
1500	23.0	26.2	31.0	23.8	22.0	17.0	19.5		
1600	21.4	26.0	25.7	22.7	21.5	16.2	18.3		
1700	19.7	25.1	24.0	20.1	18.5	13.0	18.2		
1800	18.8	24.7	23.8	17.8	14.3	9.8	16.4		
1900	15.0	23.6	21.4	14.0	9.0	10.0	15.8		
2000	11.4	22.6	17.6	12.5	6.5	11.0	15.6		
2100	11.5	22.9	17.2	11.8	5.0	11.7	16.0		
2200	11.6	22.8	15.0	10.0	4.2	12.0	18.2		
2300	11.5	21.7	13.7	9.6	3.4	12.2	19.0		
2400	11.2	20.3	14.0	8.9	3.0	12.4	18.7		

S-1 AIR TEMPERATURES (Continued)

Time	10/3	11/3	12/3	13/3	14/3	15/3	16/3	17/3	Remarks
0100		10.4	4.0	12.1	21.6	16.6	17.5	12.8	Start
0200		12.1	3.8	12.1	22.3	16.0	17.7	12.0	OT 1316/10
0300		13.4	5.0	12.1	22.5	16.1	18.1	12.0	TT 1316
0400		13.5	3.9	12.3	22.0	16.3	18.5	10.9	MT 23.5
0500		14.4	2.5	12.7	21.3	16.2	18.7	10.3	GT 23.9
0600		15.1	2.5	13.3	21.0	16.4	18.1	10.5	
0700		15.8	4.6	14.0	21.1	16.7	18.6	12.6	End
0800		15.9	5.4	14.2	21.0	17.0	19.3	13.5	OT 1510/17
0900		15.8	7.0	14.8	21.0	17.0	20.0	15.0	TT 1310 AB
1000		16.1	8.1	15.2	20.8	17.1	20.5	16.9	MT 18.7
1100		16.0	9.3	16.0	20.1	17.2	21.5	18.0	GT 18.7
1200		16.0	10.6	16.8	20.1	17.9	22.6	18.7	
1300		15.8	12.2	16.5	20.2	18.1	22.5		
1400	21.5	15.5	11.9	15.2	20.1	18.2	22.0		
1500	21.8	14.0	12.1	15.1	19.9	18.6	22.3		
1600	19.0	13.0	12.7	16.5	19.8	18.8	21.8		
1700	16.0	12.1	13.0	16.2	19.0	18.2	21.5		
1800	13.8	10.2	13.1	15.7	18.3	18.0	21.0		
1900	11.9	9.0	13.4	16.2	17.7	17.8	20.0		
2000	10.3	7.9	13.0	16.9	17.2	17.7	18.1		
2100	9.8	7.0	12.5	18.0	17.1	17.2	9.5		
2200	9.1	6.9	12.7	19.0	16.8	17.1	7.2		
2300	9.5	6.8	13.4	19.8	16.6	17.0	11.8		
2400	9.6	6.0	12.7	21.0	16.5	17.5	12.1		

Time	17/3	18/3	19/3	20/3	21/3	22/3	23/3	24/3	Remarks
0100		21.3	9.7	6.6	18.0	17.0	24.1	20.0	Start
0200		21.2	9.3	6.1	18.3	18.0	24.1	20.0	OT 1510/17
0300		20.0	9.2	5.0	19.0	17.6	24.2	20.7	TT 1510
0400		21.0	6.0	6.9	20.4	16.7	24.0	21.0	MT 18.7
0500		21.9	5.7	9.1	20.2	17.0	23.5	21.9	GT 20.7
0600		22.4	7.3	8.0	20.1	17.1	23.0	22.0	
0700		22.7	8.0	10.5	17.5	17.3	22.8	22.2	End
0800		23.1	8.3	12.0	16.7	17.5	22.6	22.4	OT 1520/24
0900		24.0	11.1	12.8	19.6	18.4	21.7	22.7	TT 1500
1000		23.9	14.7	14.2	18.0	18.6	21.7	23.4	MT 24.3
1100		23.1	14.8	14.7	17.1	20.3	21.5		GT 22.5
1200		24.3	17.8	15.0	16.8	22.0	20.3		
1300		26.0	16.9	15.6	16.4	22.8	19.0		
1400		27.3	14.9	15.7	16.8	23.3	18.6		
1500		27.8	13.0	15.8	17.1	22.5	18.1		
1600	20.8	23.5	12.0	16.0	17.9	22.1	18.2		
1700	20.9	16.0	10.0	16.1	18.0	22.0	18.3		
1800	21.0	12.8	8.0	16.0	17.9	22.5	19.0		
1900	21.0	14.8	7.3	15.9	17.9	22.5	18.9		
2000	21.1	13.9	8.1	15.8	18.1	23.1	19.2		
2100	21.0	12.1	6.9	15.9	18.6	23.5	19.5		
2200	21.1	10.1	7.9	16.1	18.0	23.7	19.7		
2300	21.3	8.4	5.0	16.5	17.9	23.8	19.9		
2400	21.4	9.0	5.3	17.1	18.0	24.0	19.9		

S-1 AIR TEMPERATURES (Continued)

Time	24/3	25/3	26/3	27/3	28/3	29/3	30/3	31/3	Remarks
0100		23.6	20.2	20.2	5.0	3.5	8.0	8.8	Start
0200		23.5	20.9	19.7	5.8	3.9	8.3	8.9	OT 1530/24
0300		23.1	22.4	19.0	7.0	3.2	9.5	7.0	TT 1500
0400		22.5	21.8	19.1	8.9	2.1	11.1	6.7	MT 24.3
0500		17.1	22.9	19.3	9.0	1.7	13.0	6.4	GT 24.5
0600		17.3	22.9	19.3	10.2	3.5	14.2	5.8	
0700		19.8	21.4	19.7	10.0	5.7	14.1	5.9	End
0800		22.2	20.0	20.1	11.9	7.2	13.4	5.7	OT 1340/31
0900		24.7	18.7	19.4	12.5	5.0	15.0	6.2	TT 1230 AB
1000		25.1	20.4	21.6	13.6	6.5	17.0	8.6	MT 13.5
1100		24.5	21.8	22.1	13.7	8.0	18.2	10.3	GT 13.0 (1230)
1200		24.3	22.5	22.7	15.5	12.2	18.8	12.1	
1300		25.1	23.1	23.8	14.7	11.9	18.2		
1400		25.0	23.1	21.9	10.1	12.5	18.1		
1500	24.5	24.2	23.2	15.5	9.2	11.0	18.1		
1600	25.0	24.3	22.1	14.3	10.0	9.0	17.7		
1700	25.0	25.0	21.9	14.2	7.5	7.1	15.0		
1800	25.2	24.9	20.8	14.0	4.6	6.5	12.9		
1900	25.8	24.5	20.5	14.3	4.8	5.7	12.5		
2000	26.9	23.9	20.6	13.1	4.2	5.0	11.9		
2100	25.3	23.8	20.5	9.8	3.9	4.1	11.7		
2200	25.0	22.9	20.5	11.5	3.1	4.0	11.0		
2300	24.7	22.4	20.6	12.0	3.0	5.3	10.2		
2400	24.2	21.2	20.4	9.3	3.2	7.0	9.4		

Time	31/3	1/4	2/4	3/4	4/4	5/4	6/4	7/4	Remarks
0100		7.5	11.0	9.9	16.8	18.0	17.2	7.0	Start
0200		7.7	9.1	11.3	16.2	18.5	17.0	7.3	OT 1345/31
0300		9.4	9.0	10.0	17.6	18.7	17.2	8.0	TT 1345
0400		10.2	7.7	11.8	17.2	18.9	17.9	8.2	MT 13.5
0500		10.6	6.2	10.2	17.3	19.0	16.4	8.3	GT 15.0
0600		11.9	8.3	10.3	19.2	17.7	16.1	9.7	
0700		13.0	9.9	13.0	19.3	18.1	15.0	9.0	End
0800		13.1	10.4	14.1	20.6	18.3	14.9	9.0	OT 1430/7
0900		14.0	9.7	15.0	23.0	18.9	16.0	10.5	TT 1230 AB
1000		15.3	12.5	17.4	24.3	20.7	17.0	13.3	MT 15.0
1100		15.9	12.7	17.1	22.8	21.5	16.7	14.6	GT 15.8
1200		16.2	12.9	17.1	21.2	21.9	18.1	14.9	
1300		16.9	12.0	16.7	21.6	21.9	19.1		
1400	14.0	16.9	11.8	16.8	22.0	22.0	18.5		
1500	13.0	16.0	8.5	15.3	21.7	21.8	18.0		
1600	12.1	13.1	4.8	16.0	21.2	21.3	17.0		
1700	11.8	13.6	6.0	16.0	21.0	20.3	14.5		
1800	7.9	15.3	7.2	16.9	20.0	20.3	12.0		
1900	6.6	17.0	7.7	17.1	19.7	20.9	11.0		
2000	5.5	16.8	8.2	16.5	20.1	20.5	10.0		
2100	5.5	14.7	6.8	16.0	19.0	19.0	9.3		
2200	6.0	14.8	7.9	16.6	19.4	17.8	8.9		
2300	4.5	15.0	10.0	15.4	19.1	16.7	8.6		
2400	6.1	15.0	10.2	17.8	19.9	17.0	8.2		

S-1 AIR TEMPERATURES (Continued)

Time	7/4	8/4	9/4	10/4	11/4	12/4	13/4	14/4	Remarks
0100		12.0	20.7	23.5	21.9	18.7	21.5	16.0	Start
0200		15.8	21.3	24.2	21.7	16.5	22.6	16.7	OT 1430/7
0300		16.7	21.2	24.5	22.0	16.0	21.0	18.7	TT 1430
0400		16.9	21.4	24.3	22.1	15.1	19.8	20.0	MT 15.0
0500		17.8	21.5	23.7	21.6	15.1	19.7	20.1	GT 15.7
0600		18.0	22.0	24.0	21.9	14.0	21.0	19.8	
0700		17.6	22.0	23.8	22.2	16.0	21.1	20.0	End
0800		19.0	23.0	24.2	23.1	16.8	20.9	19.9	OT 1415/14
0900		21.9	23.8	24.3	23.7	17.5	21.0	20.3	TT 1200 (ink blur)
1000		17.5	24.5	24.5	24.1	19.9	21.0	20.5	MT 19.0
1100		17.2	24.2	24.0	25.2	20.0	21.0	19.6	GT 20.5 (1200)
1200		18.3	24.0	23.9	25.3	20.0	21.1		
1300		17.6	23.8	23.5	25.0	20.4	21.2		1200/8 to 1600/10 =
1400		17.0	22.7	23.2	24.5	21.0	21.1		±0.5 due blurred trace
1500	15.2	16.2	22.8	22.6	23.9	21.4	21.2		
1600	13.4	16.1	22.3	21.9	23.9	21.6	21.1		
1700	13.0	17.0	22.0	21.8	23.9	21.9	21.3		
1800	12.5	18.1	22.1	21.3	23.2	21.7	21.2		
1900	12.8	18.4	22.1	20.4	22.6	21.5	21.5		
2000	14.6	19.0	22.3	21.0	22.1	21.0	20.4		
2100	15.2	19.4	22.9	21.1	22.8	19.9	21.0		
2200	14.1	18.8	23.0	21.8	22.7	21.0	21.5		
2300	14.5	19.5	23.1	21.7	20.5	22.7	21.7		
2400	12.0	20.0	23.1	21.5	18.7	22.1	19.2		

Time	14/4	15/4	16/4	17/4	18/4	19/4	20/4	21/4	Remarks
0100		9.9	12.3	11.0	10.0	1.8	-3.5	-0.2	Start
0200		10.0	12.1	10.9	10.2	0.0	-4.2	-0.5	OT 1415/14
0300		10.1	12.1	10.8	7.0	-2.5	-5.1	-1.0	TT 1415
0400		12.3	11.9	11.0	3.7	-1.2	-5.2	-1.6	MT 19.0
0500		13.1	11.5	11.0	1.0	-2.0	-5.6	-6.0	GT 21.0
0600		12.5	11.5	11.0	0.0	-1.1	-5.7	-9.2	
0700		11.9	11.2	11.3	- 0.5	-1.4	-5.9	-9.7	End
0800		12.7	11.1	11.7	0.7	-0.3	-5.8	-9.0	OT 1215/21
0900		13.0	11.2	12.0	1.1	2.1	-4.5	-5.0	TT 1100 AB
1000		13.1	11.1	12.7	1.7	2.7	-3.2	-4.5	MT -6.5
1100		13.2	11.3	12.4	2.2	4.9	-2.3		GT -4.5 (1100)
1200		13.5	11.4	12.3	3.7	5.0	-1.9		
1300		13.8	11.0	12.7	4.9	3.2	-1.3		Time and temperature
1400		13.1	11.0	12.1	4.5	3.2	-2.1		fully corrected
1500	21.0	12.6	10.7	11.8	4.0	1.0	-3.2		1545/14
1600	17.9	12.3	10.1	11.5	2.0	2.1	-2.9		
1700	16.0	12.8	9.8	11.3	1.0	1.0	-1.6		Time and temperature
1800	12.0	12.7	9.9	11.1	3.9	-0.4	-3.3		noted accurate
1900	12.3	12.5	9.5	10.9	2.5	-1.6	-3.0		1230/15
2000	11.0	12.4	9.8	10.6	0.1	-1.3	-2.2		
2100	10.9	12.6	10.0	10.3	- 0.2	-2.4	-1.0		
2200	9.8	12.7	10.9	10.1	- 0.1	-2.1	-0.1		
2300	9.1	12.6	10.9	10.0	0.0	-2.3	-0.1		
2400	7.7	12.3	11.0	10.1	0.4	-2.9	0.0		

S-1 AIR TEMPERATURES (Continued)

Time	21/4	22/4	23/4	24/4	25/4	26/4	27/4	28/4	Remarks
0100		-4.8	14.1	13.0					Start
0200		-6.0	13.9	12.8					OT 1218/21
0300		-2.1	13.7	13.3					TT 1228
0400		-2.5	14.0	12.8					MT -6.5
0500		-2.3	14.1	12.9					GT -5.5
0600		0.2	14.1	12.9					
0700		1.4	13.7	13.4					2400/22 to 1500/24
0800		3.3	13.4	13.9					probably snow
0900		2.8	13.2	14.7					damped
1000		5.0	12.9	13.4					
1100		6.2	12.9	12.6					1500/24 record ends
1200		8.4	13.0	13.9					(bad weather)
1300	- 5.4	6.0	12.9	15.5					
1400	- 6.9	6.3	13.0	16.0					
1500	- 8.2	4.0	13.1	16.4					
1600	- 9.0	4.1	13.0						
1700	- 8.9	7.8	13.1						
1800	- 9.8	7.9	13.1						
1900	-10.7	9.7	13.0						
2000	- 9.8	12.2	13.0						
2100	-10.5	13.6	13.2						
2200	-10.8	13.6	13.2						
2300	-10.0	14.0	13.3						
2400	- 6.8	13.9	13.2						

Time	28/4	29/4	30/4	1/5	2/5	3/5	4/5	5/5	Remarks
0100		6.0	8.8	7.2	-0.9	-3.3	1.0	-4.8	Start
0200		6.1	8.1	7.4	-1.6	-3.7	2.1	-2.9	OT 1030±30/28
0300		5.9	7.5	7.2	-2.3	-3.5	3.2	-1.0	TT 1000
0400		6.0	7.1	7.0	-3.0	-2.9	4.5	0.1	MT 9.5
0500		6.2	6.7	7.0	-3.3	-3.3	4.8	-0.3	GT 4.0
0600		6.0	7.0	7.0	-3.6	-3.9	4.9	-2.1	
0700		5.9	7.0	7.2	-4.2	-3.2	5.0	-5.5	End
0800		7.0	6.6	7.4	-4.8	-2.2	4.9	-6.9	OT 1130±30/5
0900		7.4	7.0	7.3	-4.7	-1.5	4.5	-7.1	TT 1000
1000		7.3	7.2	7.5	-3.1	-0.7	4.7	-5.1	MT 0.0
1100	3.7	8.8	7.3	7.4	-2.2	0.0	4.8		GT -5.0
1200	3.8	8.0	7.2	6.9	-1.9	0.3	5.0		
1300	3.5	7.5	7.1	6.4	-2.0	0.8	4.8		Constant temperature
1400	3.0	6.9	6.9	5.0	-3.4	0.7	4.3		error due bad setting
1500	3.4	6.0	6.3	3.0	-4.5	0.3	4.0		
1600	4.0	6.1	5.8	1.0	-4.9	0.1	3.8		
1700	4.5	6.6	5.4	0.5	-4.8	-0.2	2.0		
1800	4.9	7.2	5.5	0.7	-4.7	-0.9	0.1		
1900	5.2	8.5	5.3	0.9	-4.1	-0.8	0.0		
2000	5.9	7.7	5.5	1.7	-4.0	-0.1	0.7		
2100	4.7	7.5	5.7	2.2	-3.5	0.1	0.8		
2200	5.9	7.0	6.0	2.0	-2.7	0.0	0.1		
2300	4.8	6.7	6.5	1.9	-2.2	0.1	-2.0		
2400	5.8	7.9	6.9	0.3	-2.8	0.1	-4.6		

S-1 AIR TEMPERATURES (Continued)

Time	5/5	6/5	7/5	8/5	9/5	10/5	11/5	12/5	Remarks
0100		4.5	-9.9	5.2					Start
0200		4.9	-9.7	7.2					OT 1100±30/5
0300		4.3	-9.8	9.6					TT 1100
0400		3.4	-8.8						MT 0.0
0500		2.0	-8.0						GT 0.0
0600		-5.3	-6.3						
0700		-10.0	-4.1						Possibly some damping
0800		-11.9	-2.4						
0900		-11.9	-1.1						Instrument failure
1000		-12.6	-2.0						0400/8
1100	0.0	-13.4	-2.7						
1200	3.0	-12.3	-0.2						
1300	-2.5	-10.5	2.0						
1400	-1.4	-9.8	2.1						
1500	1.0	-7.0	2.3						
1600	2.7	-6.7	2.8						
1700	3.5	-7.3	3.1						
1800	5.3	-8.4	3.0						
1900	6.5	-9.0	3.0						
2000	7.0	-9.9	3.5						
2100	7.3	-10.3	3.6						
2200	7.2	-10.8	3.6						
2300	7.1	-10.6	4.0						
2400	5.2	-10.3	4.7						

Time	12/5	13/5	14/5	15/5	16/5	17/5	18/5	19/5	Remarks
0100		17.1	15.0	25.0					Start
0200		17.0	15.8						OT 1215±30/12
0300		16.2	15.7						TT 1215
0400		16.1	16.8						MT 19.0
0500		16.0	15.0						GT 19.0
0600		15.0	16.2						
0700		14.8	16.1						Instrument failure
0800		14.0	17.2						0100/15
0900		12.7	21.0						
1000		14.0	19.3						
1100		14.6							
1200		16.2							
1300	19.0	16.9							
1400	18.3	16.8	19.5						
1500	17.8	16.2	21.0						
1600	17.6	16.9	23.0						
1700	17.5	16.7	23.5						
1800	17.5	16.5	23.5						
1900	17.2	16.8	22.5						
2000	17.5	17.0	23.0						
2100	18.0	18.0	24.2						
2200	17.6	19.0	24.5						
2300	17.8	17.7	24.6						
2400	17.2	16.1	24.7						

Time	19/5	20/5	21/5	22/5	23/5	24/5	25/5	26/5	Remarks
0100		23.6	19.8	10.2	-5.4	1.3	13.9	16.3	Start
0200		23.8	19.6	9.9	-5.0	1.5	13.8	16.1	OT 1045/19
0300		25.0	19.2	9.2	-4.3	2.0	13.8	15.8	TT ink blot 0700 to
0400		26.9	18.8	8.7	-4.1	5.0	13.9	15.6	1300
0500		27.5	18.7	8.8	-4.1	6.2	13.7	15.4	MT 25.0
0600		27.6	18.1	6.1	-4.3	6.5	13.8	15.2	GT 25.8 (1300)
0700		28.1	17.0	5.9	-5.0	6.7	14.0	15.1	
0800		28.1	16.2	5.0	-5.6	6.9	14.2	15.1	End
0900		28.0	16.0	1.1	-5.7	7.0	14.7	15.0	OT 1100/26
1000		27.2	15.8	0.9	-5.7	7.4	15.0	14.6	TT 1040
1100		26.7	15.3	-1.0	-5.3	8.0	15.1		MT 15.0
1200		26.1	15.0	-5.0	-5.1	8.5	15.6		GT 14.4
1300	25.8	25.0	14.4	-6.8	-4.2	9.2	15.8		
1400	25.7	23.8	13.6	-6.9	-3.4	10.0	15.9		Smooth trace, perhaps
1500	26.0	22.5	13.0	-7.0	-3.0	10.8	16.0		damped
1600	25.9	21.6	12.0	-6.9	-2.7	11.2	16.1		
1700	25.7	21.0	11.8	-7.0	-2.2	12.0	16.6		
1800	25.7	20.3	11.7	-7.9	-1.2	12.4	16.8		
1900	25.6	20.0	11.5	-7.9	-0.8	13.0	16.9		
2000	25.4	20.0	11.6	-8.0	-0.2	13.9	16.9		
2100	25.0	20.0	11.8	-7.6	0.5	14.0	16.9		
2200	24.8	20.0	11.9	-6.0	1.0	14.1	16.9		
2300	24.2	20.1	11.4	-6.1	1.1	14.1	16.8		
2400	24.0	20.1	11.0	-5.8	1.2	14.0	16.6		

Time	26/5	27/5	28/5	29/5	30/5	31/5	1/6	2/6	Remarks
0100		6.7	11.0	7.0	5.6	-0.1	1.3	-5.8	Start
0200		6.9	11.0	7.7	5.1	0.0	1.7	-5.2	OT 1100/26
0300		6.7	11.3	7.0	5.0	0.1	1.6	-5.1	TT ink blot 1000 to
0400		6.4	11.0	6.6	4.5	0.1	1.8	-5.1	1200
0500		6.1	10.9	6.6	4.1	0.2	1.9	-5.3	MT 15.0
0600		6.0	10.9	6.8	3.0	0.1	1.9	-5.4	GT 15.0 (1200)
0700		5.5	10.0	7.2	2.0	0.1	1.8	-6.0	
0800		5.1	8.8	7.3	1.6	0.0	1.9	-6.1	End
0900		4.6	7.4	7.5	1.1	0.0	1.9	-6.3	OT 1100
1000		4.9	6.7	8.9	0.9	-0.1	1.9	-6.0	TT 1110
1100		6.1	6.2	9.0	0.8	-0.1	1.8	-5.6	MT Not recorded
1200	15.0	8.0	6.0	9.3	0.3	-0.1	1.6		GT -5.6
1300	14.7	9.0	5.2	9.7	0.1	0.0	1.5		
1400	12.8	9.9	2.8	10.6	-0.2	1.0	0.9		Smooth trace, perhaps
1500	12.0	10.3	2.7	11.9	-0.6	3.0	0.3		damped
1600	10.6	10.9	3.9	11.9	-0.8	3.6	0.0		
1700	9.7	11.2	4.4	11.5	-0.6	3.1	-0.9		
1800	8.8	12.1	5.0	11.0	-0.2	2.9	-1.9		
1900	8.0	12.8	5.3	10.0	0.0	2.8	-3.9		
2000	7.6	13.3	6.0	9.1	0.1	2.4	-4.0		
2100	7.1	13.0	5.9	8.2	0.1	2.3	-4.7		
2200	7.0	12.1	6.3	7.8	0.0	1.3	-5.0		
2300	6.6	11.7	6.1	7.5	-0.2	1.5	-5.3		
2400	6.4	11.0	6.0	6.9	-0.1	1.6	-5.7		

S-1 AIR TEMPERATURES (Continued)

Time	2/6	3/6	4/6	5/6	6/6	7/6	8/6	9/6	Remarks
0100		-7.5	8.6	-8.0	-5.2	-2.3	12.0	2.5	Start
0200		-9.0	8.0	-9.7	-5.6	-2.4	12.0	2.1	OT 1100/2
0300		-9.3	6.0	-10.0	-5.8	-2.6	11.8	1.0	TT 1050
0400		-9.4	5.8	-10.5	-6.0	-2.7	11.5	-1.0	MT NR
0500		-10.0	5.9	-10.3	-6.0	-2.5	11.2	-5.5	GT -4.1
0600		-11.7	5.7	-8.9	-5.8	-2.5	11.1	-6.9	
0700		-11.9	5.4	-8.1	-4.8	-2.1	11.1	-7.2	End
0800		-11.9	5.1	-8.3	-4.0	-2.2	11.0	-7.5	OT 1115±30/9
0900		-11.8	4.0	-8.8	-3.4	-4.3	11.0	-8.5	TT 1045
1000		-12.0	2.7	-7.9	-3.1	-4.2	11.0	-9.9	MT -14.0
1100		-11.0	1.2	-7.0	-3.0	-4.2	10.9		GT -11.0
1200	-4.0	-7.9	1.0	-6.1	-2.6	-2.5	11.0		
1300	-3.7	-6.0	1.1	-5.5	-2.2	-0.3	10.9		Smooth trace,
1400	-3.9	-3.1	0.9	-5.3	-2.0	-0.1	10.8		perhaps damped
1500	-4.2	-0.8	0.3	-5.1	-1.9	2.0	10.8		
1600	-4.5	-0.5	-0.2	-5.0	-1.8	5.0	10.7		Certainly damped
1700	-4.7	0.2	-1.0	-5.0	-1.8	8.0	10.5		after 0200/8
1800	-4.8	2.9	-3.8	-4.9	-2.0	10.4	10.4		
1900	-4.9	3.2	-5.0	-5.0	-2.4	11.0	10.4		
2000	-4.9	4.2	-5.2	-5.3	-2.3	10.9	10.5		
2100	-5.0	4.8	-5.4	-5.5	-2.4	11.1	10.5		
2200	-4.9	5.0	-5.7	-5.3	-2.7	11.3	10.0		
2300	-5.0	6.4	-6.0	-5.1	-2.8	11.9	7.0		
2400	-5.0	8.0	-6.4	-5.0	-2.9	11.8	3.1		

Time	9/6	10/6	11/6	12/6	13/6	14/6	15/6	16/6	Remarks
0100		-20.0	-19.0	-26.0	-19.0	-22.5	-3.6	0.7	Start
0200		-19.5	-23.0	-26.4	-14.3	-22.7	-3.9	0.8	OT 1115±30/9
0300		-20.3	-25.2	-27.0	-12.8	-22.4	-3.8	1.0	TT 1045
0400		-22.7	-25.7	-27.2	-12.9	-22.3	-3.7	1.8	MT -14.0
0500		-24.0	-25.9	-27.8	-12.8	-22.6	-3.6	1.7	GT -14.0
0600		-23.7	-25.9	-28.0	-20.0	-22.0	-3.4	1.4	
0700		-22.8	-26.0	-23.0	-20.4	-22.1	-3.3	0.1	End
0800		-21.0	-26.3	-22.8	-19.2	-20.9	-3.4	0.6	OT 1100/16
0900		-18.2	-26.5	-23.0	-19.3	-16.5	-3.8	0.5	TT 1045
1000		-18.1	-25.4	-25.0	-13.0	-15.0	-3.5	0.6	MT 4.0
1100		-14.0	-24.0	-25.5	-12.7	-13.0	-3.0		GT 0.8
1200	-13.2	-12.2	-22.2	-26.1	-11.8	-11.2	-2.9		
1300	-13.0	-10.8	-22.0	-26.9	-12.0	-6.9	-2.7		Perhaps damped
1400	-16.0	-10.2	-22.6	-25.0	-11.7	-6.6	-2.1		after 1800/13
1500	-17.0	-11.8	-23.3	-22.8	-12.2	-6.2	-1.9		
1600	-16.9	-11.8	-24.6	-22.9	-13.5	-5.5	-2.0		
1700	-16.3	-12.0	-24.5	-22.8	-17.0	-4.8	-2.0		
1800	-17.0	-12.3	-21.2	-22.9	-20.0	-3.3	-1.8		
1900	-17.3	-12.5	-19.0	-25.0	-20.7	-3.2	-1.3		
2000	-17.0	-12.3	-20.0	-28.1	-20.9	-2.5	-1.2		
2100	-17.2	-12.0	-22.1	-30.0	-21.3	-3.0	-1.1		
2200	-18.5	-12.0	-22.3	-30.1	-21.5	-3.2	-0.2		
2300	-19.4	-12.7	-24.0	-29.7	-22.0	-3.1	0.8		
2400	-20.0	-13.5	-25.0	-29.0	-22.3	-3.2	0.9		

S-1 AIR TEMPERATURES (Continued)

Time	16/6	17/6	18/6	19/6	20/6	21/6	22/6	23/6	Remarks
0100		1.0	2.7	- 2.6	-13.1	- 2.5	-12.0	-23.0	Start
0200		1.1	2.0	- 3.8	-13.4		-10.0	-23.5	OT 1100/16
0300		1.6	1.7	- 5.0	-15.0		- 9.1	-24.0	TT 1100
0400		2.0	1.6	- 5.8	-22.0		- 9.1	-24.8	MT 4.0
0500		1.7	1.6	- 6.0	-25.1		- 9.2	-24.9	GT 4.0
0600		1.1	1.8	- 6.6	-27.3		- 9.2	-25.0	
0700		2.0	2.0	- 6.5	-27.5		- 9.4	-25.1	End
0800		3.0	2.1	- 6.7	-27.1		- 9.2	-25.1	OT 1230/23
0900		2.9	1.9	- 6.8	-27.5	-12.5	- 9.2	-25.1	TT Ink blot AB
1000		2.4	2.0	- 6.8	-26.1	-11.7	- 9.2	-25.1	1200 to 1800
1100		2.2	2.2	- 6.7	-25.8	-10.5	- 9.3	-25.2	MT -28.0
1200	1.9	1.6	2.3	- 7.0	-23.0	-10.2	-11.6	-25.0	GT -25.0 (1200)
1300	0.0	1.1	2.2	- 7.1	-18.5	-10.6	-14.0		
1400	-1.6	1.7	2.0	- 7.2	-13.9	-11.0	-15.5		Ink blot 1600/20
1500	-1.0	2.6	1.7	- 7.5	- 8.5	-11.1	-17.0		to 0800/21
1600	-0.5	2.9	1.0	- 7.9		-11.1	-17.6		
1700	0.5	2.4	0.5	- 8.0		-11.0	-18.3		Perhaps damped
1800	1.8	2.5	0.1	- 8.5		- 9.4	-18.9		
1900	1.0	2.6	-0.2	-10.0		- 9.1	-19.1		
2000	0.3	2.8	-0.6	-13.0		- 9.2	-19.9		
2100	0.2	3.0	-1.0	-13.5		-10.0	-20.3		
2200	0.5	3.0	-1.8	-14.0		-10.8	-20.7		
2300	0.7	3.0	-2.0	-13.9		-11.5	-21.0		
2400	0.9	3.0	-2.1	-13.5		-12.0	-22.0		

Time	23/6	24/6	25/6	26/6	27/6	28/6	29/6	30/6	Remarks
									1300/23 June to 1300/2 July instrument failure

S-1 AIR TEMPERATURES (Continued)

Time	30/6	1/7	2/7	3/7	4/7	5/7	6/7	7/7	Remarks
0100				12.6	9.5	-7.6	3.0	13.0	Start
0200				12.1	9.2	-7.1	5.7	12.4	OT 1400/2
0300				12.2	9.0	-6.4	8.0	12.8	TT 1400
0400				12.1	8.9	-5.7	10.2	13.1	MT 9.5
0500				12.0	7.0	-5.1	11.0	15.0	GT 9.5
0600				11.0	4.0	-5.8	11.9	15.4	
0700				11.1	0.0	-4.0	11.9	16.3	End
0800				11.1	-0.9	-3.9	12.0	16.9	OT 1030/9
0900				10.1	-0.9	-4.9	12.0	17.2	TT 1050
1000				10.0	-0.9	-6.2	12.1	18.1	MT 11.0
1100				9.9	-0.8	-5.7	12.2	18.3	GT 5.0
1200				10.1	-0.6	-5.8	12.4	18.9	
1300				10.5	-0.4	-3.5	12.4		Late start due bad
1400			9.5	10.4	-1.5	-4.9	12.6		weather and clock
1500			8.7	10.2	-3.9	-6.8	12.7		repairs
1600			8.8	10.0	-3.3	-6.5	12.8	20.8	
1700			8.5	9.9	-2.6	-6.5	12.8	20.8	Perhaps damped after
1800			8.2	9.2	-2.1	-5.2	13.0	20.6	0600/6
1900			9.5	9.3	-3.0	-2.0	13.1	19.9	
2000			9.8	9.1	-3.8	-0.8	13.0	19.9	
2100			10.0	9.3	-4.2	-0.1	12.9	20.1	
2200			10.5	9.4	-5.5	-0.2	12.8	19.0	
2300			11.9	9.5	-6.4	-0.5	13.7	17.4	
2400			12.5	9.7	-7.1	0.0	13.3	17.5	

Time	7/7	8/7	9/7	10/7	11/7	12/7	13/7	14/7	Remarks
0100		18.1	10.2	18.4	19.7	13.3	6.0	-7.0	Start
0200		18.6	10.2	18.6	18.2	13.7	5.9	-7.1	OT 1030±30/9
0300		18.4	10.3	18.0	18.3	13.8	5.7	-8.4	TT 1030
0400		18.3	10.2	18.0	18.2	13.3	5.4	-9.1	MT 11.0
0500		18.5	10.2	18.0	18.0	12.9	5.5	-9.1	GT 13.0
0600		18.3	10.0	18.4	17.5	12.1	5.6	-8.5	
0700		18.6	7.1	18.7	17.2	12.0	5.5	-7.8	For corrections to
0800		18.7	5.3	19.0	17.0	11.4	5.4	-6.8	1030/9 see previous
0900		18.8	3.0	18.9	17.0	11.3	1.0		week
1000		18.9	3.5	19.2	17.0	11.2	- 2.0		
1100		19.0	15.0	20.0	16.2	11.2	- 2.0		Clock probably stopped
1200		19.1	17.3	20.1	15.8	11.3	- 5.1		0850/14
1300		19.2	18.5	20.1	15.7	11.1	- 9.3		
1400		19.6	19.2	20.5	14.9	10.9	-10.2		Perhaps damped until
1500		19.4	19.8	20.8	14.0	10.0	-10.3		0800/13
1600		18.9	19.9	20.6	14.0	8.9	-10.0		
1700		18.2	20.0	20.7	13.8	8.3	- 7.1		
1800		17.1	19.9	20.5	13.6	8.1	- 4.8		
1900		16.4	19.7	20.2	13.5	8.0	- 3.5		
2000		14.2	19.9	20.1	13.5	8.2	- 2.8		
2100		13.2	19.7	20.0	13.5	8.0	- 2.9		
2200		12.2	19.0	20.1	13.5	7.0	- 2.8		
2300		11.6	19.0	20.1	13.3	7.0	- 6.0		
2400		11.0	18.8	19.2	13.2	6.3	- 7.3		

S-1 AIR TEMPERATURES (Continued)

Time	14/7	15/7	16/7	17/7	18/7	19/7	20/7	21/7	Remarks
0100		12.0	1.0	15.5	15.8	22.3	10.0		Start
0200		12.6	- 2.2	15.1	16.0	22.5	10.6		OT 1200±30/14
0300		12.0	- 5.0	14.0	16.5	22.5	11.8		TT 1145
0400		11.8	- 7.0	13.0	17.0	22.4	11.9		MT -2.0
0500		11.2	- 9.0	12.0	17.3	21.0	11.8		GT -1.0
0600		11.9	-10.2	11.5	17.8	18.9	11.5		
0700		12.7	-11.0	11.0	18.4	17.0	10.8		Perhaps damped in
0800		13.1	-11.2	11.2	18.9	15.5	10.0		second half of week
0900		13.7	-11.5	11.5	19.0	14.0	9.5		
1000		13.8	-11.8	11.2	19.0	12.0	9.0		Clock probably
1100		13.2	-11.3	12.0	19.0	10.0	8.3		stopped 1420/20
1200	- 0.8	12.5	-10.0	13.0	19.0	8.1	7.6		
1300	- 0.2	12.0	- 8.0	14.3	19.1	7.2	6.2		Max. after stoppa
1400	0.1	11.3	- 5.5	15.0	19.0	6.5	5.4		5.0; min. -3.0
1500	1.5	10.6	- 4.0	15.4	19.1	5.7			
1600	1.8	8.1	- 2.2	15.8	19.8	5.5			
1700	0.1	6.4	- 1.0	16.0	20.0	5.9			
1800	1.3	4.4	3.0	16.1	20.8	7.0			
1900	3.2	3.5	10.1	16.0	19.3	8.0			
2000	5.0	2.8	10.4	16.0	20.1	8.4			
2100	9.7	2.5	13.0	16.0	20.3	8.8			
2200	9.5	2.0	14.0	14.9	21.1	8.9			
2300	9.7	2.1	16.0	15.8	22.0	8.9			
2400	10.8	1.7	16.2	15.9	22.2	9.0			

Time	21/7	22/7	23/7	24/7	25/7	26/7	27/7	28/7	Remarks
0100		-15.0	-10.0	4.8	- 6.0	- 0.5			Start
0200		-14.8	- 9.0	5.0	- 6.8	- 2.9			OT 1130±30/21
0300		-14.3	- 9.1	10.0	- 7.5	- 4.0			TT 1150
0400		-14.2	-10.5	12.2	- 8.2	- 4.3			MT -2.0
0500		-14.0	- 8.0	12.0	- 8.5	- 4.8			GT 0.0
0600		-13.7	- 2.2	12.9	- 8.8	- 4.9			
0700		-13.2	- 3.0	11.0	-11.0	- 4.9			Clock probably
0800		-13.5	-10.0	5.8	-14.0	- 4.9			stopped 1920/
0900		-14.0	-17.0	4.5	-13.8	- 5.0			
1000		-13.8	-17.3	4.5	-14.2	- 5.0			Max. after st
1100		-11.5	-17.8	4.0	-13.0	- 5.5			page -24.7; m
1200	0.9	-11.1	-15.1	3.0	-11.8	- 8.4			-37.0
1300	2.3	-10.8	-15.9	2.0	-10.5	-12.0			
1400	2.1	-13.0	-17.1	2.1	-10.0	-15.5			
1500	1.2	-15.0	-14.7	2.0	- 8.5	-20.9			
1600	1.1	-15.1	-14.4	1.8	- 8.0	-20.9			
1700	1.1	-16.1	-15.0	1.0	- 5.0	-24.0			
1800	0.9	-16.9	-16.1	0.9	- 5.1	-26.0			
1900	- 1.0	-14.0	-19.0	0.3	- 4.1	-27.1			
2000	- 8.0	-13.0	-14.5	- 0.4	- 2.6				
2100	-11.0	-10.0	-11.0	- 1.0	- 4.5				
2200	-14.9	-13.0	- 5.5	- 3.9	- 3.8				
2300	-15.0	-12.8	1.0	- 4.6	- 2.4				
2400	-14.5	-13.3	2.1	- 5.7	- 0.8				

S-1 AIR TEMPERATURES (Continued)

Time	28/7	29/7	30/7	31/7	1/8	2/8	3/8	4/8	Remarks
0100			- 6.0	3.2	- 6.2	- 9.0	-12.8	-3.0	Start
0200			-12.5	4.1	- 3.8	- 3.5	-12.2	-2.6	OT 1100±30/28
0300			-15.0	4.8	- 0.7	- 1.0	-12.0	-2.0	TT Instrument
0400			-20.9	4.7	- 1.3	- 0.1	-10.1	-1.7	failure
0500			-22.0	3.8	- 3.0	1.3	-10.3	-1.9	MT -29.0
0600			-19.7	5.1	- 4.4	0.3	-12.8	-1.5	GT Instrument
0700			-19.8	7.3	- 3.8	0.8	-14.5	-1.2	failure
0800			-21.0	6.2	- 3.0	- 0.2	-15.3	-3.9	
0900			-20.0	5.1	- 0.8	- 4.0	-12.0	-5.1	End
1000			-10.0	4.0	0.0	- 6.5	-12.4	-5.0	OT 1100±30/4
1100			- 7.9	1.0	- 0.2	- 7.5	-10.0	-4.8	TT 1100
1200		-16.0	- 8.1	- 0.7	0.1	- 8.0	- 6.5		MT -1.0
1300		-10.0	- 6.7	- 3.0	- 0.9	- 8.5	- 5.3		GT -4.7
1400		0.1	- 5.4	- 4.2	- 6.0	- 9.8	- 4.0		
1500		- 5.0	- 2.8	- 7.0	- 6.0	- 9.7	- 2.8		No continuous
1600		- 0.9	6.4	- 8.5	- 8.1	- 9.5	- 2.9		trace until
1700		0.0	7.3	-13.0	- 8.0	- 9.0	- 2.0		1200/29 but after
1800		- 0.3	6.0	-11.2	- 9.1	- 7.9	- 1.5		that time and
1900		- 2.8	5.1	-11.6	-11.0	- 4.2	- 1.1		temperature
2000		- 2.9	4.5	-10.8	-11.4	- 3.2	- 0.7		probably correct
2100		- 5.1	4.2	-14.0	-12.0	- 3.4	- 0.3		
2200		- 3.2	4.9	-10.5	-12.9	- 6.2	- 0.4		
2300		- 5.9	4.8	- 5.8	-12.5	-10.0	- 0.5		
2400		- 5.1	4.0	- 5.7	-11.7	-12.5	- 0.8		

Time	4/8	5/8	6/8	7/8	8/8	9/8	10/8	11/8	Remarks
0100		- 6.3	- 0.5	- 8.0	-14.0	-8.4			Start
0200		- 6.5	- 3.2	-10.1	-13.2	-5.5			OT 1100±30/4
0300		- 7.0	- 4.0	-13.0	-13.8	-4.2			TT 1120
0400		- 1.0	- 3.5	-15.3	-16.9	-4.0			MT -1.0
0500		0.0	- 4.0	-15.4	-20.0	-3.7			GT -1.5
0600		1.1	- 5.0	-13.5	-20.5	-3.3			
0700		7.0	- 6.0	-18.0	-20.5	-3.5			Ink probably
0800		7.1	- 7.9	-15.7	-20.2	-3.2			stopped at 1600/9;
0900		6.3	- 8.2	-17.0	-19.0	-2.0			record otherwise
1000		6.1	- 8.1	-15.8	-17.0	-1.0			good
1100		10.0	- 8.0	-13.6	-16.8	0.0			
1200	-0.2	12.0	- 9.1	-13.0	-13.2	1.0			
1300	-1.0	10.0	- 9.0	-13.2	-14.0	1.2			
1400	1.8	9.0	- 9.8	-14.0	-14.0	1.5			
1500	-1.0	9.8	-11.4	-15.0	-14.1	1.8			
1600	-6.5	8.5	-11.8	-15.9	-14.0	1.1			
1700	-9.3	8.0	-11.5	-15.2	-15.2				
1800	-9.0	6.2	- 9.2	-16.4	-16.0				
1900	-8.0	4.0	- 6.3	-16.9	-15.0				
2000	-5.0	3.9	- 8.1	-16.4	-13.2				
2100	-3.4	2.2	- 9.2	-17.2	-12.0				
2200	-5.1	4.5	- 9.1	-17.1	-10.4				
2300	-8.0	5.3	- 7.0	-16.0	- 9.8				
2400	-4.9	0.0	- 7.1	-13.8	-10.0				

Time	11/8	12/8	13/8	14/8	15/8	16/8	17/8	18/8	Remarks
0100		-13.4	-16.0	- 3.1	-12.5	- 2.0	10.3		Start
0200		-13.5	-16.1	- 4.7	-12.3	- 0.8	9.9		OT 1100±30/11
0300		-13.5	-15.4	- 3.4	-12.2	8.0	9.0		TT 1100
0400		-13.7	-15.1	- 5.0	-12.2	10.1	9.0		MT -11.0
0500		-13.9	-14.5	- 5.9	-14.0	10.0	9.0	17.2	GT -10.0
0600		-15.0	-13.3	- 6.0	-12.0	10.0	8.9	16.8	
0700		-16.0	-14.0	-10.0	- 9.7	9.7	9.6	16.4	End
0800		-16.0	-12.5	-10.5	-14.0	9.9	9.8	16.4	OT 1205±30/19
0900		-15.5	- 9.9	- 7.8	-12.0	9.9	9.5	16.3	TT 2200/18
1000		-15.2	-10.2	- 5.8	- 9.6	9.9	9.6	16.2	MT 8.0
1100	-10.0	-16.0	- 8.5	- 8.7	- 8.0	9.8	9.8	16.3	GT 11.8 (2200/1
1200	- 9.1	-15.8	- 7.0	- 7.1	- 7.2	9.2	10.1	16.2	
1300	- 9.1	-15.5	- 6.9	- 6.0	- 9.0	6.7	10.9	16.0	Record change
1400	- 9.2	-15.6	- 7.1	- 4.1	-12.0	7.5	10.9	15.9	delayed 1 day;
1500	- 9.5	-16.0	- 8.0	- 3.2	-13.2	9.0	10.5	16.0	clock probably
1600	-10.4	-20.5	- 8.2	- 3.2	-11.7	10.6	9.9	16.1	stopped 2200/1
1700	-10.7	-22.3	- 8.1	- 4.0	-13.5	13.0	9.0	16.0	
1800	-10.9	-20.0	- 8.2	- 3.2	-12.2	14.3	8.1	15.0	Max. after sto
1900	-11.8	-21.4	- 9.3	- 5.0	-10.0	15.2	7.0	14.1	page 11.8; min
2000	-12.3	-22.3	-11.8	- 7.2	- 9.2	15.3	6.1	13.9	4.1
2100	-12.7	-20.5	-15.0	-10.8	-10.5	15.0	8.1	13.1	
2200	-12.8	-19.8	- 8.5	-12.0	-12.1	19.0	11.3	11.8	
2300	-12.9	-19.0	- 4.4	-12.5	-10.6	11.4	14.0		
2400	-13.0	-16.6	- 4.5	-13.7	- 8.4	10.8	16.0		

Time	18/8	19/8	20/8	21/8	22/8	23/8	24/8	25/8	Remarks
0100			0.2						Start
0200			0.1						OT 1205/19
0300			1.2						TT 1205
0400			1.1						MT 8.0
0500			1.2						GT 9.0
0600			2.0						
0700			4.0						Started one day lat
0800			4.2						
0900			4.0						Clock stopped 1915/
1000			3.1						
1100			3.0						
1200			3.6						
1300		10.0	4.8						
1400		10.5	3.4						
1500		10.2	- 2.0						
1600		10.3	- 5.2						
1700		9.5	- 7.0						
1800		6.4	- 9.0						
1900		5.9	-15.0						
2000		2.9							
2100		2.0							
2200		1.2							
2300		0.8							
2400		0.2							

S-1 AIR TEMPERATURES (Continued)

Time	25/8	26/8	27/8	28/8	29/8	30/8	31/8	1/9	Remarks
0100				-3.8	9.0	12.8	8.9	6.8	Start
0200				-3.9	10.0	12.9	8.9	6.7	OT 1520/27
0300				-6.0	10.4	12.9	8.5	6.6	TT 1520
0400				-10.0	11.0	12.9	8.5	6.5	MT -7.0
0500				-11.3	11.3	12.9	8.3	6.5	GT -7.8
0600				-11.8	11.5	12.8	8.3	6.4	
0700				-11.8	11.8	12.5	8.2	6.4	End
0800				-11.3	11.9	12.2	8.3	6.3	OT 1200±30/2
0900				-10.5	11.9	12.1	8.3	6.3	TT 1100
1000				-9.5	11.9	12.1	8.4	6.3	MT 4.5
1100				-8.0	11.9	12.0	8.6	6.3	GT 2.8
1200				-6.5	12.0	11.5	9.0	6.3	
1300				-5.8	12.0	11.1	9.1	6.3	Begins and ends late
1400				-5.0	12.0	11.0	9.1		
1500				-4.2	12.1	10.9	9.2		Almost certainly
1600			-8.0	-3.7	12.1	10.5	9.1		damped
1700			-8.8	-2.4	12.1	10.3	9.2	5.0	
1800			-8.5	-0.7	12.1	10.0	8.5	4.9	
1900			-8.2	1.0	12.1	9.9	8.3	4.5	
2000			-7.5	2.1	12.1	9.8	7.8	4.2	
2100			-6.0	4.7	12.3	9.3	7.7	4.2	
2200			-4.8	6.0	12.3	9.2	7.3	4.0	
2300			-4.2	7.0	12.6	9.1	7.3	4.0	
2400			-4.0	7.7	12.8	9.0	7.0	4.0	

Time	1/9	2/9	3/9	4/9	5/9	6/9	7/9	8/9	Remarks
0100		4.0		1.1	-7.5	-2.6	-18.0	-9.2	Start
0200		4.0		0.5	-7.0	-3.0	-18.6	-9.1	OT 1200±30/2
0300		3.9		-1.0	-7.4	-3.2	-18.9	-9.0	TT 1120
0400		3.9		-3.0	-6.0	-3.5	-19.0	-8.8	MT 4.5
0500		3.4		-4.7	-5.3	-3.7	-19.0	-8.2	GT 4.2
0600		3.2		-5.9	-4.7	-4.0	-19.0	-7.9	
0700		3.0		-7.0	-4.0	-4.0	-19.0	-7.0	End
0800		2.9	2.1	-7.9	-3.4	-4.2	-19.1	-6.6	OT 1200/8
0900		2.8	1.9	-8.0	-2.9	-4.6	-19.1	-5.8	TT 1130
1000		2.9	1.9	-7.9	-2.2	-4.9	-18.5	-5.0	MT 3.0
1100		2.9	2.0	-7.5	-1.8	-4.8	-18.0	-4.4	GT -4.0
1200		4.2	2.1	-7.0	-0.9	-4.3	-17.1		
1300		4.1	2.2	-6.0	0.0	-4.2	-16.0		Ink blur 2300/2 to
1400		4.0	2.3	-5.6	0.1	-4.5	-13.7		0700/3
1500		3.8	2.5	-5.1	0.2	-5.0	-13.4		
1600		3.5	2.5	-5.6	0.1	-7.1	-13.2		Probably damped
1700		3.2	2.5	-6.5	0.0	-10.0	-12.4		
1800		3.1	2.5	-7.9	-0.5	-11.5	-11.8		
1900		3.0	2.5	-8.3	-0.8	-13.0	-11.2		
2000		3.0	2.2	-8.8	-1.1	-14.0	-11.0		
2100		3.0	2.1	-8.9	-1.3	-15.0	-10.4		
2200		2.9	2.1	-8.9	-1.7	-16.0	-10.1		
2300			2.0	-8.5	-2.0	-17.0	-10.0		
2400			1.8	-8.0	-2.2	-17.7	-9.7		

S-1 AIR TEMPERATURES (Continued)

Time	8/9	9/9	10/9	11/9	12/9	13/9	14/9	15/9	Remarks
0100		-2.7							Start
0200		-3.2							OT 1200/8
0300		-3.8							TT 1200
0400		-4.1							MT 3.0
0500		-4.6							GT 14.5
0600		-5.2							
0700									Thermograph probably
0800									allowed to become too
0900									warm before replacing,
1000									data probably accurate
1100									
1200									Clock probably froze
1300	4.5								0700/9
1400	2.0								
1500	0.7								
1600	-0.5								
1700	-0.9								
1800	0.0								
1900	0.8								
2000	1.0								
2100	1.0								
2200	0.0								
2300	-1.4								
2400	-2.0								

Time	15/9	16/9	17/9	18/9	19/9	20/9	21/9	22/9	Remarks
0100			-20.5	-27.5	-4.7	- 7.2	- 4.8		Start
0200			-21.2	-28.3	-3.1	-11.5	- 5.2		OT 1205/15
0300			-22.0	-28.4	-3.4	-14.5	- 6.5		TT Instrument
0400			-23.5	-28.1	-3.5	-17.5	- 7.6		failure
0500			-26.5	-28.2	-3.2	-21.0	- 8.0		MT -22.0
0600			-28.0	-27.0	-3.4	-23.0	-10.0		GT Instrument
0700			-28.8	-27.1	-3.2	-23.5	-10.5		failure
0800			-29.2	-27.1	-3.5	-24.0	-11.0		
0900			-29.0	-27.0	-3.8	-25.0	-12.2		Probably due per
1000			-28.2	-25.0	-3.9	-25.0	-12.3		failure only
1100			-28.0	-24.6	-4.0	-25.0	-13.8		1640/16 to
1200			-27.3	-24.1	-4.1	-25.2	-14.9		1915/21 shows
1300			-27.6	-24.0	-4.3	-25.2	-15.4		
1400			-28.0	-23.5	-4.8	-25.3	-16.2		No checks possi-
1500			-28.0	-22.7	-5.1	-24.8	-17.6		ble but record
1600			-27.5	-21.5	-5.5	-23.2	-18.2		looks good apar
1700		-20.5	-26.7	-20.0	-6.1	-20.5	-18.4		from some proba-
1800		-20.8	-25.2	-18.5	-6.5	-16.0	-18.2		ble damping
1900		-20.9	-24.0	-18.3	-6.5	-10.0	-18.1		
2000		-20.7	-23.0	-14.5	-6.6	- 7.9			
2100		-20.3	-21.1	- 9.0	-6.7	- 6.8			
2200		-20.1	-21.2	- 7.0	-6.9	- 6.0			
2300		-20.0	-22.0	- 6.0	-7.0	- 5.8			
2400		-20.0	-25.3	- 5.0	-7.0	- 5.0			

S-1 AIR TEMPERATURES (Continued)

Time	22/9	23/9	24/9	25/9	26/9	27/9	28/9	29/9	Remarks
0100		0.4	3.9						Start
0200		0.9	3.3						OT 1200/22
0300		1.8	3.3						TT 1200
0400		2.7							MT -6.0
0500		3.5							GT -6.9
0600		4.5							
0700		5.2							Clock stopped
0800		6.3							0300/24
0900		6.8							
1000		7.0							Probably snow damped
1100		7.1							
1200	-6.9	7.0							
1300	-7.1	6.8							
1400	-7.3	6.5							
1500	-7.0	6.2							
1600	-6.4	5.8							
1700	-6.0	5.4							
1800	-5.6	5.2							
1900	-5.0	5.1							
2000	-4.2	5.0							
2100	-3.0	4.8							
2200	-2.0	4.3							
2300	-1.0	4.1							
2400	-0.3	4.0							

Time	29/9	30/9	1/10	2/10	3/10	4/10	5/10	6/10	Remarks
0100		-16.2	- 9.2	-17.9	-22.8	-17.0	-8.8	-7.6	Start
0200		-16.2	- 9.1	-17.8	-23.1	-16.2	-8.9	-8.0	OT NR
0300		-16.8	- 9.3	-18.8	-24.7	-15.6	-9.0	-8.3	TT 1250/29
0400		-16.9	- 9.0	-20.2	-24.8	-14.8	-9.0	-8.9	MT -15.0
0500		-16.0	-12.3	-20.3	-25.0	-12.2	-9.0	-8.9	GT -3.7
0600		-13.2	-14.8	-20.0	-24.9	-10.2	-9.0	-9.0	
0700		-11.2	-14.7	-20.0	-24.7	- 8.7	-9.0	-9.0	End
0800		-10.1	-14.8	-19.5	-24.1	- 7.9	-8.9	-9.0	OT NR
0900		-13.9	-14.7	-18.0	-22.6	- 7.2	-8.5	-8.9	TT 1200/6
1000		-11.5	- 8.9	-16.5	-19.0	- 7.0	-8.0	-8.0	MT -8.5
1100		- 4.0	-13.0	-14.5	-15.4	- 6.9	-7.0	-7.0	GT -6.2
1200		- 2.8	-12.4	-13.6	-11.6	- 6.8	-6.5	-6.2	
1300	- 3.6	- 1.1	-12.0	-13.0	-10.4	- 6.9	-6.1		Unexplained
1400	- 4.3	- 1.1	-11.7	-12.8	-10.2	- 6.9	-6.2		error best
1500	- 6.0	- 1.3	-11.5	-12.6	- 9.8	- 6.9	-6.2		averaged over
1600	- 7.2	- 1.4	-11.6	-12.5	-10.9	- 7.0	-6.4		whole period
1700	-10.0	- 2.0	-11.8	-13.3	-12.0	- 7.2	-6.8		
1800	-15.3	- 5.0	-11.7	-15.2	-13.4	- 7.6	-6.9		Possibly damped
1900	-18.3	- 7.0	-11.9	-16.5	-17.0	- 7.9	-6.9		after 2400/3
2000	-18.6	- 9.2	-11.9	-16.6	-18.7	- 8.1	-6.9		
2100	-18.5	-10.0	-12.3	-16.4	-18.5	- 8.4	-7.0		
2200	-18.1	-10.8	-15.0	-19.4	-18.2	- 8.6	-7.0		
2300	-17.5	-10.3	-17.4	-21.5	-17.8	- 8.7	-7.1		
2400	-16.6	- 9.8	-18.0	-22.4	-17.8	- 8.9	-7.3		

S-1 AIR TEMPERATURES (Continued)

Time	6/10	7/10	8/10	9/10	10/10	11/10	12/10	13/10	Remarks
0100		-19.3	-12.0	-14.0	-16.0	-23.9	-8.7	-2.2	Start
0200		-19.1	-12.0	-14.8	-19.6	-23.9	-7.8	-2.2	OT NR
0300		-19.1	-12.1	-14.9	-21.0	-23.7	-7.0	-2.2	TT 1450/6
0400		-19.1	-12.2	-15.1	-22.5	-23.1	-6.9	-2.2	MT -8.5
0500		-18.7	-12.3	-15.0	-22.3	-22.6	-6.9	-2.2	GT -13.0
0600		-18.6	-12.3	-14.8	-22.0	-21.8	-6.9	-2.1	
0700		-18.3	-12.0	-14.0	-21.8	-20.8	-7.0	-2.0	End
0800		-17.7	-11.7	-13.8	-21.0	-19.6	-6.9	-1.7	OT NR
0900		-15.2	-11.4	-13.1	-19.0	-18.5	-6.5	-1.7	TT 1200/13
1000		-14.3	-11.0	-13.0	-17.5	-17.5	-6.0	-1.4	MT 9.0
1100		-13.4	- 8.5	-12.7	-16.0	-16.6	-5.0	-1.0	GT -0.5
1200		-12.4	- 7.0	-12.6	-11.3	-15.8	-4.2	-0.5	
1300		-11.9	- 6.2	-12.2	-10.0	-15.0	-3.1		Unexplained
1400		-11.7	- 5.8	-12.3	- 9.9	-14.5	-2.8		error best
1500	-13.1	-11.5	- 5.6	-12.4	-15.0	-14.0	-2.2		averaged ov
1600	-17.9	-11.5	- 6.0	-12.4	-20.1	-13.8	-2.1		whole period
1700	-20.1	-11.4	- 8.5	-12.6	-22.6	-13.4	-2.0		
1800	-20.2	-11.5	-11.1	-13.0	-26.0	-13.0	-2.0		Probably
1900	-20.2	-11.7	-12.6	-13.0	-26.9	-12.8	-2.0		slightly
2000	-20.2	-11.8	-12.7	-13.5	-26.8	-12.3	-2.0		damped
2100	-20.1	-11.8	-12.9	-13.8	-26.4	-12.0	-2.1		
2200	-20.1	-11.9	-13.0	-14.0	-26.0	-11.1	-2.2		
2300	-20.0	-11.9	-13.0	-14.4	-25.0	-10.2	-2.2		
2400	-19.8	-12.0	-13.5	-14.8	-24.2	- 9.7	-2.3		

Time	13/10	14/10	15/10	16/10	17/10	18/10	19/10	20/10	Remarks
0100		-1.4	3.8	-0.3	-0.2	-3.7	-6.2	- 3.0	Start
0200		-1.7	3.5	-0.4	-0.1	-3.9	-6.0	- 3.7	OT NR
0300		-3.1	3.3	-0.8	0.0	-4.7	-5.8	- 8.0	TT 1230/13
0400		-3.3	3.2	-0.9	0.1	-5.1	-5.6	-10.2	MT 9.0
0500		-3.8	3.1	-0.9	0.4	-5.1	-5.2	-10.6	GT 9.0
0600		-4.0	3.0	-0.9	0.6	-5.9	-4.9	-10.7	
0700		-3.0	3.0	-0.9	0.7	-6.0	-4.7	-10.8	End
0800		-0.3	3.1	-0.4	0.8	-6.1	-4.5	-10.5	OT NR
0900		3.0	5.0	0.0	0.7	-6.1	-4.3	-10.0	TT 1050/20
1000		4.0	6.1	0.3	0.4	-6.2	-3.2	- 9.5	MT NR
1100		5.0	6.6	0.6	0.3	-6.0	-2.2		GT -8.8
1200		5.8	6.8	0.9	0.0	-5.5	-2.0		
1300	9.1	6.9	7.0	1.0	-0.2	-5.2	-1.5		2100/17 to
1400	9.3	6.9	6.9	1.7	-0.4	-5.1	-1.3		1300/19 are
1500	9.7	6.9	6.5	1.9	-0.6	-5.1	-1.1		±0.5 due in
1600	9.0	6.7	6.1	1.9	-0.8	-5.2	-0.8		blur
1700	5.3	6.3	5.0	1.4	-1.4	-5.6	-0.3		
1800	4.2	5.8	3.6	0.5	-2.0	-6.0	-0.2		Probably
1900	4.0	5.4	2.2	0.2	-2.6	-6.0	-0.1		damped
2000	2.9	5.0	1.5	0.1	-3.0	-6.5	-0.1		especially
2100	1.0	4.8	0.8	0.1	-3.0	-6.5	-0.4		after 2400/
2200	-0.8	4.3	0.1	0.1	-3.0	-6.5	-1.0		
2300	-1.0	4.1	-0.1	0.0	-3.0	-6.5	-1.5		
2400	-1.2	3.9	-0.1	-0.2	-3.2	-6.5	-2.2		

S-1 AIR TEMPERATURES (Continued)

Time	20/10	21/10	22/10	23/10	24/10	25/10	26/10	27/10	Remarks
0100		-1.5	-8.0	-3.9	-1.8	8.0	-5.3	-2.0	Start
0200		-1.1	-9.5	-3.0	0.4	8.0	-5.9	-5.0	OT NR
0300		-1.1	-10.1	-2.3	-3.0	6.0	-6.0	-6.2	TT 1200/20
0400		-1.0	-9.7	-2.2	-4.6	5.1	-5.0	-6.1	MT NR
0500		-0.8	-8.7	-1.4	-2.0	5.0	-4.5	-3.0	GT 7.0
0600		0.8	-8.2	-1.0	0.3	6.0	-3.0	-1.0	
0700		4.7	-5.0	-0.5	3.5	9.0	-0.2	1.0	End
0800		5.1	-0.8	0.8	5.1	10.1	3.5	3.9	OT NR
0900		6.6	5.0	1.8	5.0	14.0	5.0	8.0	TT 1040/27
1000		6.7	6.2	2.0	4.2	14.1	8.8	10.0	MT 20.2
1100		6.6	6.9	2.5	4.8	12.5	10.0		GT 10.8
1200		6.3	6.0	4.9	4.0	14.8	9.2		
1300	5.4	8.0	5.1	4.8	3.8	13.3	8.4		Unexplained
1400	5.9	7.0	5.0	4.9	3.9	15.9	8.0		error best
1500	5.0	5.0	4.9	2.5	4.3	16.0	8.1		averaged over
1600	3.0	3.1	2.8	0.9	5.1	9.4	7.8		whole period
1700	0.5	-1.0	2.0	-0.4	5.3	5.0	5.0		
1800	-1.6	-5.4	-1.1	-2.5	5.9	1.2	3.1		
1900	-1.8	-9.0	-2.0	-3.9	5.9	-1.0	1.2		
2000	-2.0	-10.6	-2.9	-3.1	6.0	-1.3	0.0		
2100	-2.0	-11.0	-3.0	-2.5	6.0	-2.0	1.1		
2200	-2.0	-8.3	-3.2	-2.1	7.0	-4.3	-0.2		
2300	-1.9	-7.3	-3.6	-2.1	7.4	-5.0	-2.2		
2400	-1.7	-7.0	-3.9	-2.2	8.0	-5.8	-1.7		

Time	27/10	28/10	29/10	30/10	31/10	1/11	2/11	3/11	Remarks
0100		-6.0	-7.0	6.2	11.9	16.1	12.6	16.1	Start
0200		-6.0	-7.4	7.0	11.8	16.0	12.1	16.2	OT NR
0300		-4.2	-7.0	10.0	11.7	15.3	12.5	16.1	TT Blot 1000-
0400		-3.9	-5.0	11.3	11.9	15.4	12.9	15.8	1440/27
0500		-2.5	-2.8	11.5	12.0	16.0	13.3	15.4	MT 20.2
0600		0.3	-3.5	12.1	12.5	17.0	14.1	15.7	GT Blot
0700		5.0	0.4	12.7	13.3	17.0	15.0	17.2	
0800		8.4	3.8	12.9	14.0	17.3	15.9	18.3	End
0900		10.0	7.0	12.7	14.7	17.9	18.0	19.3	OT NR
1000			12.8	12.1	15.4	17.9	18.0	20.0	TT 1200/3
1100		9.6	14.0	12.1	16.0	18.5	16.5	21.0	MT 19.0
1200		11.8	14.0	12.8	16.3	19.9	15.9	21.0	GT 16.0
1300		18.0	17.0	13.0	16.7	21.0	15.8		
1400		13.2	19.1	13.0	17.2	23.1	16.0		
1500	18.0	12.7	16.0	12.9	17.3	23.2	15.7		
1600	13.2	9.7	13.7	12.1	16.9	21.2	15.0		
1700	10.0	7.0	9.0	11.8	16.0	20.7	14.0		
1800	6.8	5.5	2.3	11.2	15.8	18.8	13.1		
1900	2.0	0.0	1.0	11.8	15.4	17.0	12.8		
2000	0.2	-1.0	0.0	12.0	15.4	15.2	12.2		
2100	0.8	-2.0	2.0	12.7	15.6	14.3	12.0		
2200	-1.1	-5.0	4.3	12.6	16.0	14.1	11.7		
2300	-1.1	-6.3	4.8	12.0	16.0	14.0	11.3		
2400	-1.8	-7.5	5.2	11.9	16.1	12.8	11.0		

S-1 AIR TEMPERATURES (Continued)

Time	3/11	4/11	5/11	6/11	7/11	8/11	9/11	10/11	Remarks
0100		6.2	12.3	16.2	16.5	13.8	7.0	4.3	Start
0200		2.2	12.0	15.5	15.9	13.9	7.1	4.1	OT NR
0300		2.0	12.5	15.9	15.0	14.0	6.0	4.0	TT 1150/3
0400		3.1	12.4	16.0	14.9	12.1	7.9	4.1	MT 19.0
0500		3.0	12.0	16.2	15.0	9.9	3.9	5.6	GT 19.0
0600		7.3	13.0	16.5	16.0	9.4	4.0	7.2	
0700		11.0	16.0	16.9	17.1	11.0	5.2	10.0	End
0800		14.0	13.2	17.1	18.0	13.9	7.0	12.5	OT NR
0900		15.0	13.9	18.0	19.8	13.5	9.0	16.0	TT 1120/10 AB
1000		19.8	16.9	18.5	20.0	23.8	13.7	19.5	MT NR
1100		21.0	17.6	18.8	20.0	23.2	18.5	23.5	GT 24.8 (1120)
1200	19.0	19.6	19.2	18.8	20.8	23.1	22.6		
1300	17.8	17.0	18.5	19.0	19.8	23.0	23.0		
1400	17.1	16.2	15.4	19.0	17.8	22.9	23.3		
1500	16.7	18.0	14.4	19.0	16.3	22.8	25.0		
1600	16.2	18.1	13.6	17.8	15.9	20.0	26.8		
1700	14.8	16.5	13.2	16.5	15.4	16.5	25.0		
1800	13.0	15.2	13.6	15.9	15.0	13.0	20.0		
1900	12.5	14.2	14.0	14.5	14.9	10.0	15.2		
2000	11.3	13.4	15.0	14.1	14.0	8.0	12.3		
2100	11.0	12.0	14.9	14.3	12.0	7.1	9.5		
2200	6.1	11.3	17.9	14.9	11.8	6.4	7.6		
2300	6.0	11.5	16.6	15.2	12.5	6.8	6.1		
2400	7.1	11.7	16.6	16.2	13.0	7.1	5.0		

Time	10/11	11/11	12/11	13/11	14/11	15/11	16/11	17/11	Remarks
0100		14.0	15.9	16.6	16.5	22.6	22.0	20.4	Start
0200		12.5	15.9	16.4	16.1	22.7	21.9	20.1	OT NR
0300		12.6	16.0	16.3	16.3	22.0	21.8	20.1	TT 1240/10
0400		13.6	16.9	16.2	16.6	22.5	21.7	20.3	MT NR
0500		15.5	17.0	16.5	17.0	23.1	21.6	21.0	GT 30.0
0600		16.8	19.2	17.0	17.1	23.5	21.9	22.3	
0700		19.5	20.0	17.8	18.5	23.1	22.1	23.4	End
0800		22.5	19.1	18.6	19.0	23.0	22.9	26.0	OT NR
0900		24.7	20.6	18.0	20.0	22.9	24.0	28.1	TT 1030/17
1000		24.8	20.0	18.9	21.1	22.5	24.8		MT 26.0
1100		23.0	20.0	20.0	21.0	22.6	24.8		GT 28.2
1200		22.8	21.0	20.1	20.2	22.7	25.5		
1300	30.0	22.7	21.4	21.0	20.0	22.8	27.2		Possible da
1400	28.8	21.0	21.3	21.7	20.1	22.9	27.8		ing after
1500	28.9	19.9	20.9	22.0	20.3	22.4	27.3		2400/13
1600	26.2	18.9	20.0	21.2	20.7	22.8	28.0		
1700	24.5	18.0	19.0	21.5	21.5	22.3	27.0		
1800	23.2	17.8	18.1	21.1	21.9	22.2	24.1		
1900	20.0	17.4	17.7	19.7	22.1	22.4	20.8		
2000	15.7	16.0	17.2	18.2	22.2	22.0	20.9		
2100	12.0	15.2	16.8	17.5	22.6	22.0	21.0		
2200	8.4	15.1	16.9	17.0	22.9	21.9	21.0		
2300	7.0	15.3	16.7	16.7	22.9	21.9	21.1		
2400	12.1	15.5	16.5	16.6	22.8	22.0	20.9		

S-1 AIR TEMPERATURES (Continued)

Time	17/11	18/11	19/11	20/11	21/11	22/11	23/11	24/11	Remarks
0100		6.5	1.0	2.0	9.8	9.9	16.0	12.8	Start
0200		6.6	- 1.5	0.1	9.9	9.9	17.2	13.0	OT NR
0300		6.1	- 2.1	1.0	9.9	10.6	17.0	13.3	TT 1100/17
0400		7.0	- 1.2	3.0	9.5	10.7	16.6	13.5	MT 26.0
0500		8.0	0.6	6.0	9.7	11.5	16.4	13.6	GT 26.0
0600		8.9	2.9	5.1	10.3	13.2	17.1	13.8	
0700		10.9	5.0	6.9	10.8	14.0	17.7	15.0	End
0800		12.8	8.3	9.9	11.1	14.0	17.1	16.5	OT NR
0900		14.0	12.0	10.9	11.9	15.8	17.1	19.0	TT 1600/24
1000		14.9	13.6	11.4	12.1	15.2	17.1	21.0	MT 26.0
1100	23.2	14.9	14.5	13.5	12.6	15.1	17.6		GT 21.6
1200	19.8	14.4	14.3	13.2	12.9	17.0	17.9		
1300	18.5	13.8	14.1	17.0	13.0	21.0	17.9		
1400	18.1	13.0	13.9	15.0	12.0	21.0	18.0		
1500	19.3	12.1	12.9	12.5	11.1	19.1	17.0	21.4	
1600	19.0	12.2	12.0	12.3	10.2	19.2	16.1	21.6	
1700	17.5	12.7	11.4	12.8	10.1	19.0	15.4		
1800	15.0	11.4	11.0	11.0	10.0	18.9	14.9		
1900	12.5	6.0	10.6	10.0	9.9	18.2	14.1		
2000	11.0	2.4	7.2	10.9	9.3	15.2	13.9		
2100	10.5	4.0	6.0	10.4	9.1	10.5	13.3		
2200	9.6	6.3	5.1	9.8	9.0	13.3	12.5		
2300	8.0	6.8	3.1	9.2	9.3	14.9	12.2		
2400	5.3	7.3	2.2	9.5	9.7	15.0	12.1		

Time	24/11	25/11	26/11	27/11	28/11	29/11	30/11	1/12	Remarks
0100		10.3	2.1	14.0	13.9	10.9	1.5	- 1.9	Start
0200		10.9	4.8	14.1	13.5	10.5	2.2	- 2.5	OT 1530±30/24
0300		10.4	7.9	15.7	14.1	10.0	2.1	- 1.0	TT 1600
0400		10.1	2.8	15.9	14.1	7.8	2.0	6.0	MT 26.0
0500		5.8	5.0	16.8	15.0	3.7	2.0	8.1	GT 28.0
0600		7.0	11.8	17.7	16.2	6.8	3.8	11.5	
0700		13.0	15.0	20.1	18.2	11.0	9.0	15.0	End
0800		18.5	13.2	20.6	18.1	16.9	14.8	18.6	OT NR
0900		20.8	17.0	22.1	19.8	19.9	19.0	18.6	TT 1215/1
1000		19.4	21.6	21.1	20.0	25.0	19.0	20.8	MT 29.0
1100		19.1	21.5	24.0	21.6	26.5	21.8	23.5	GT 27.2
1200		18.9	21.0	28.1	21.9	26.1	21.5	27.2	
1300		17.9	21.4	28.0	21.0	26.0	21.0		
1400		17.5	21.0	26.1	19.0	26.5	20.9		
1500		17.3	23.0	24.1	19.7	27.0	22.0		
1600	28.0	16.8	21.9	24.9	19.9	25.0	22.5		
1700	27.0	17.0	19.8	22.1	20.0	20.9	22.4		
1800	25.8	17.0	19.9	19.9	20.1	18.5	19.2		
1900	21.0	17.1	18.0	16.0	20.0	14.0	14.0		
2000	15.0	16.0	17.6	14.3	14.2	10.1	6.0		
2100	12.0	15.0	16.5	14.4	10.5	7.0	1.0		
2200	11.0	14.1	14.9	14.2	9.9	4.8	- 1.0		
2300	9.9	10.0	14.2	15.1	9.5	3.8	- 3.0		
2400	10.0	4.9	14.8	14.8	10.1	4.0	- 2.4		

S-1 AIR TEMPERATURES (Continued)

Time	1/12	2/12	3/12	4/12	5/12	6/12	7/12	8/12	Remarks
0100		20.1	19.2	16.5	18.0	2.2	8.0	9.5	Start
0200		20.1	19.0	14.1	17.1	2.0	8.9	8.0	OT NR
0300		20.1	18.6	12.0	15.1	2.8	11.5	8.0	TT 1145/1
0400		20.1	18.9	17.1	17.1	5.1	14.5	8.6	MT 31.0
0500		20.3	19.0	16.0	19.0	11.5	15.8	10.5	GT 28.9
0600		20.6	19.1	16.2	22.9	18.0	15.2	12.5	
0700		20.8	19.9	20.0	25.5	20.0	18.5	15.7	End
0800		21.2	20.4	23.0	26.0	23.5	20.1	18.3	OT 1500±30/8
0900		22.0	21.3	25.7	27.3	25.7	19.9	20.2	TT 1400 AB
1000		22.9	22.4	27.9	28.0	30.5	20.0	22.0	MT 23.5
1100		23.0	24.0	27.7	30.0	31.0	20.5	22.8	GT 19.8 (1400)
1200	28.5	23.5	24.9	27.5	35.4	32.0	21.2	22.0	
1300	28.0	24.0	24.0	28.2	38.2	31.9	21.3	22.1	
1400	29.9	25.8	23.9	29.1	37.0	32.4	21.3	19.8	
1500	29.1	25.0	23.5	27.5	32.0	31.1	21.0		
1600	28.5	23.5	23.1	25.0	31.5	24.0	19.9		
1700	25.0	22.5	22.9	24.0	30.5	23.0	19.9		
1800	22.1	21.0	22.7	21.9	26.0	19.2	19.7		
1900	21.8	20.9	22.1	21.0	21.0	16.0	19.0		
2000	21.3	20.4	22.7	20.0	15.0	14.0	15.9		
2100	20.0	20.0	22.9	18.9	11.0	12.0	13.0		
2200	19.8	20.0	22.0	18.5	8.9	10.2	15.5		
2300	19.9	19.9	19.0	18.0	6.0	10.0	14.5		
2400	20.1	19.3	17.0	18.6	3.6	8.4	11.3		

Time	8/12	9/12	10/12	11/12	12/12	13/12	14/12	15/12	Remarks
0100		20.0	21.6	21.0	21.6	24.7	26.7	25.5	Start
0200		19.8	21.3	21.0	22.0	24.0	26.0	25.3	OT 1500±30/8
0300		20.0	22.0	20.3	23.0	23.6	25.9	22.0	TT 1500
0400		20.1	23.0	20.9	23.9	23.2	25.9	25.1	MT 23.5
0500		20.2	25.0	21.0	24.2	23.1	25.8	25.1	GT 21.0
0600		19.9	26.0	21.0	25.0	23.0	25.8	25.0	
0700		19.7	26.9	21.1	25.0	23.8	25.9	25.5	End
0800		20.8	27.2	21.1	25.3	25.0	26.0	26.0	OT 1130±30/15
0900		21.2	28.0	21.2	26.3	28.0	26.0	26.9	TT 1110
1000		21.0	28.8	20.9	27.0	29.8	26.1	27.5	MT 29.0
1100		24.0	28.1	20.8	27.8	30.0	26.1	28.0	GT 28.0
1200		25.0	27.8	20.8	27.9	28.8	26.2		
1300		24.0	28.8	20.9	28.0	28.5	26.4		Probably damped
1400		25.0	28.0	21.0	28.4	28.4	26.5		after 1200/11
1500	21.0	23.7	26.1	21.1	28.9	28.3	26.6		
1600	20.0	23.6	24.9	21.7	28.9	28.3	26.8		
1700	20.0	23.6	24.0	21.9	28.7	28.2	26.9		
1800	19.7	23.2	24.0	21.9	28.5	28.2	26.9		
1900	19.0	24.4	23.5	21.8	28.2	28.1	26.5		
2000	19.1	23.5	23.8	21.7	28.0	28.0	26.1		
2100	19.4	23.0	23.8	21.5	27.5	27.9	26.0		
2200	20.0	22.8	23.0	21.5	27.0	27.2	26.0		
2300	20.0	22.7	22.9	21.6	25.9	27.1	25.9		
2400	19.9	22.1	22.2	21.5	25.3	27.0	25.6		

S-1 AIR TEMPERATURES (Continued)

Time	15/12	16/12	17/12	18/12	19/12	20/12	21/12	22/12	Remarks
0100		19.9	21.9	24.1	15.0	26.3	21.8	25.1	Start
0200		21.2	22.1	24.2	19.0	26.1	23.0	25.0	OT 1130±30/15
0300		22.0	21.7	24.1	19.1	26.2	24.5	25.0	TT 1400
0400		20.9	20.8	24.1	20.3	26.1	26.0	24.9	MT 29.0
0500		23.0	22.0	25.0	23.0	26.0	26.5	24.7	GT 29.5
0600		24.7	24.3	26.4	25.3	26.8	26.1	24.3	
0700		25.2	27.5	27.1	29.0	27.7	27.1	24.2	End
0800		27.3	28.9	29.9	31.6	28.6	26.2	24.4	OT 1450/22
0900		28.6	31.0	31.4	33.0	28.4	26.3	25.0	TT 1330 AB
1000		28.9	32.1	32.6	33.5	29.2	26.2	26.5	MT 29.5
1100		30.0	32.8	37.0	33.7	29.0	26.4	27.0	GT NR
1200		31.1	35.4	36.0	32.8	29.6	26.9	29.8	
1300		34.0	36.6	32.0	31.5	29.7	27.1	29.9	Possibly damped
1400	31.4	36.0	38.0	31.4	31.0	29.9	27.0		after 1200/21
1500	31.0	36.1	37.9	29.9	33.0	30.9	26.5		
1600	31.1	34.5	36.7	29.2	31.2	31.0	25.9		
1700	30.9	32.0	37.0	27.5	31.0	31.1	25.8		
1800	30.2	29.4	37.9	27.0	29.2	30.2	25.8		
1900	24.0	28.0	35.0	26.0	28.0	25.0	25.7		
2000	20.0	26.9	29.2	25.0	27.2	21.8	25.6		
2100	16.5	24.0	26.5	23.9	26.3	18.5	25.5		
2200	18.3	23.3	26.8	23.4	26.3	15.2	25.4		
2300	21.4	23.7	25.3	20.0	26.2	15.3	25.4		
2400	21.0	23.2	29.2	15.4	26.2	16.2	25.3		

Time	22/12	23/12	24/12	25/12	26/12	27/12	28/12	29/12	Remarks
0100		27.5	20.0	16.7	12.4	21.0	21.4	10.0	Start
0200		27.1	18.9	15.8	12.6	15.8	21.1	12.0	OT 1455±30/22
0300		27.4	19.0	16.0	16.0	16.0	17.0	13.1	TT 1455
0400		27.3	22.5	16.5	20.0	18.8	14.0	12.1	MT NR
0500		29.0	23.8	18.3	21.1	21.0	15.0	12.5	GT 31.8
0600		30.4	26.0	21.0	21.9	23.5	17.4	14.8	
0700		31.6	27.5	25.0	26.0	27.0	21.5	17.0	End
0800		31.9	30.2	30.2	26.9	29.0	24.8	20.2	OT 1540/29
0900		32.5	33.1	33.7	29.0	31.0	27.5	22.1	TT 1330 AB
1000		33.7	35.2	37.9	33.2	32.2	28.4	23.0	MT 27.0
1100		35.0	36.0	36.2	33.4	34.8	30.0	24.0	GT 30.0
1200		32.0	39.9	36.4	32.8	36.7	30.7	25.8	
1300		32.1	36.7	36.3	32.0	37.6	30.1	27.7	
1400		32.0	36.0	37.4	30.3	37.0	29.9		
1500	31.8	31.9	35.2	37.0	30.5	30.2	29.9		
1600	32.2	31.3	38.5	33.2	31.8	29.0	30.0		
1700	32.9	30.2	37.5	32.0	30.0	29.0	28.5		
1800	32.1	28.9	34.0	30.1	27.1	29.0	28.0		
1900	31.5	25.7	30.0	27.8	26.5	26.1	26.0		
2000	30.2	25.9	27.6	25.0	25.0	24.9	21.8		
2100	28.5	26.0	26.0	20.0	23.9	22.1	16.0		
2200	27.1	24.3	22.0	15.8	23.8	21.9	13.0		
2300	27.1	23.0	18.0	14.0	23.0	21.9	11.2		
2400	27.0	23.3	16.3	12.4	22.0	21.8	10.0		

Time	29/12	30/12	31/12	1/1	2/1	3/1	4/1	5/1	Remarks
0100		6.0	13.8	14.4	16.0	5.2	18.8	26.8	Start
0200		4.9	13.2	14.5	16.0	5.6	19.9	27.7	OT 1540±30/29
0300		3.1	13.3	15.0	17.4	6.8	19.9	25.3	TT 1540
0400		4.8	13.1	14.0	17.9	8.4	19.0	25.1	MT 27.0
0500		8.0	13.0	15.3	17.6	12.0	18.9	25.2	GT 27.5
0600		11.6	14.2	14.3	19.7	13.9	18.3	25.7	
0700		15.0	16.5	15.7	21.8	19.0	17.6	26.0	End
0800		20.1	19.0	16.9	22.5	22.8	18.4	27.1	OT 1400±30/6
0900		24.0	24.9	17.3	25.0	22.0	19.3	27.8	TT 1400
1000		28.3	24.3	19.0	26.0	21.6	20.0	28.2	MT 35.0
1100		30.0	24.5	20.0	26.3	21.0	20.2	28.1	GT 28.8
1200		33.0	25.3	20.8	28.7	21.3	21.2	27.8	
1300		33.0	26.0	20.9	29.9	22.0	21.8	27.6	Record runs late
1400		32.2	25.8	21.0	29.9	20.8	22.5		
1500	27.0	34.1	27.2	22.6	29.0	20.8	22.8		Damped after 1800/
1600	29.3	32.1	26.0	21.2	26.3	21.0	23.0		
1700	30.0	28.0	24.0	20.4	25.8	20.7	24.0		
1800	31.1	24.4	21.9	20.3	26.7	20.5	24.7	27.7	
1900	30.0	22.0	21.0	19.9	25.0	20.1	24.0	27.2	
2000	21.5	17.3	20.2	19.4	16.8	20.0	24.9	26.2	
2100	16.0	15.8	18.5	19.3	11.0	20.1	25.0	26.1	
2200	11.3	15.9	15.2	19.0	8.4	19.7	26.0	26.3	
2300	8.5	13.9	12.6	18.5	7.0	18.5	26.9	26.2	
2400	7.0	13.7	13.0	18.0	5.6	18.6	26.5	26.1	

Time	5/1	6/1	7/1	8/1	9/1	10/1	11/1	12/1	Remarks
0100		26.0	30.4	27.0	30.2	28.5	29.9	28.7	Start
0200		26.0	29.0	24.2	30.0	28.1	30.0	28.6	OT 1400±30/6
0300		26.3	29.0	23.9	29.8	28.3	30.0	28.5	TT 1401
0400		26.8	31.8	25.1	29.9	29.0	30.1	28.8	MT 35.0
0500		28.0	32.0	27.0	30.6	29.3	30.2	29.2	GT 36.0
0600		27.9	34.9	29.4	34.0	30.2	30.8	30.0	
0700		27.9	36.8	32.4	34.2	31.8	31.0	31.0	End
0800		27.9	36.5	33.6	35.7	31.2	31.1	31.7	OT 1200/13
0900		27.9	38.0	33.5	42.0	34.0	32.0	32.5	TT 1100
1000		28.1	40.9	34.2	41.0	36.5	31.8	32.8	MT 34.0
1100		28.2	40.0	35.1	43.2	38.1	31.9	32.0	GT Blot 37.0 to 39.5
1200		28.4	39.8	35.0	43.0	37.7	31.9	31.9	
1300		28.4	40.0	34.0	38.7	38.0	32.0	31.5	Record runs late
1400		28.7	39.0	33.3	37.9	39.2	32.0		
1500		36.8	38.1	33.5	36.5	38.7	32.1		
1600		39.2	37.9	34.1	35.0	38.8	31.9		
1700		39.3	38.2	33.2	33.5	37.0	31.5		
1800		38.4	37.6	32.3	32.9	34.5	31.1	33.0	
1900		38.5	36.0	32.0	32.5	33.8	31.0	30.8	
2000		37.2	35.5	32.0	31.9	31.6	30.5	29.6	
2100		33.0	34.7	32.0	31.0	31.0	30.3	29.7	
2200		32.1	32.9	32.3	30.2	29.6	29.2	29.1	
2300		31.4	32.5	32.1	30.0	29.1	29.0	28.9	
2400		30.9	31.0	31.2	29.9	29.9	28.5	28.2	

S-1 AIR TEMPERATURES (Continued)

Time	12/1	13/1	14/1	15/1	16/1	17/1	18/1	19/1	Remarks
0100		25.1	13.0	20.4	13.5	17.5	17.9	12.2	Start
0200		21.2	12.1	21.9	15.0	18.0	17.2	12.6	OT 1205/13
0300		21.0	11.2	21.5	18.0	17.9	16.9	12.8	TT Blot 1120 to 1400
0400		19.4	15.7	20.0	19.9	17.7	17.1	13.9	MT 35.0
0500		22.0	18.0	19.7	20.5	18.5	18.0	16.0	GT Blot 31.5 to 38.0
0600		24.0	18.0	19.5	21.3	19.4	18.3	16.3	
0700		30.0	18.5	22.0	21.9	20.5	19.0	18.3	End
0800		34.9	21.3	24.5	22.2	22.3	20.0	21.0	OT 1420/20
0900		34.5	25.0	27.8	22.8	24.0	21.9	25.0	TT 1330
1000		38.2	28.2	29.0	24.1	24.1	24.0	26.4	MT 32.0
1100			34.2	30.9	26.8	24.5	26.5	28.0	GT 29.0
1200			31.3	31.0	26.9	25.1	29.4	28.4	
1300			30.8	31.8	27.1	25.1	35.0	25.2	Record runs late
1400			31.2	32.0	29.2	25.3	36.1		
1500		31.0	32.5	34.0	31.0	25.2	34.2		
1600		29.2	33.2	33.9	26.0	24.9	31.0		
1700		28.2	31.5	32.5	24.1	25.0	29.4		
1800		27.2	28.5	29.0	23.3	24.8	27.3	23.1	
1900		22.1	26.0	24.0	22.1	23.0	24.5	22.7	
2000		20.9	24.9	21.0	22.2	20.1	21.6	22.0	
2100		19.3	24.0	18.0	21.0	19.0	18.0	21.8	
2200		19.9	21.0	15.3	17.9	18.7	15.0	21.2	
2300		20.0	18.6	13.0	17.0	18.0	13.1	21.0	
2400		14.5	19.0	11.3	16.6	18.1	13.1	21.0	

Time	19/1	20/1	21/1	22/1	23/1	24/1	25/1	26/1	Remarks
0100		20.7	12.0	10.0	11.0	18.8	19.1	12.0	Start
0200		20.5	10.2	9.9	11.4	18.1	19.5	10.8	OT 1425±30/20
0300		20.4	10.8	10.0	15.0	18.0	19.3	11.7	TT 1425
0400		20.5	12.0	11.8	16.8	17.0	19.2	11.0	MT 32.0
0500		21.0	12.4	15.0	18.5	16.0	19.6	10.0	GT 38.4
0600		21.8	13.5	16.9	18.2	16.6	20.1	11.8	
0700		23.0	15.0	19.0	20.0	16.7	22.0	20.0	End
0800		25.5	18.5	22.5	25.3	18.1	22.9	23.3	OT 1100±30/25
0900		28.0	21.4	24.9	26.5	19.9	23.8	27.4	TT 1100
1000		29.8	22.8	25.5	28.7	20.2	25.5	26.5	MT 27.0
1100		29.7	23.5	26.7	29.8	21.3	25.9	26.1	GT 26.3
1200		30.1	24.6	30.1	32.5	20.8	26.0		
1300		29.9	25.8	32.1	33.8	21.0	26.2		Almost certainly
1400			25.9	33.0	31.1	20.9	28.0		set incorrectly
1500		38.5	25.8	31.0	28.5	20.8	29.4		
1600		34.5	26.0	28.2	26.9	20.0	29.9		
1700		36.4	24.7	25.2	24.7	20.0	29.0		
1800		32.0	20.0	23.8	22.3	19.9	26.6		
1900		22.0	14.3	20.0	21.0	19.9	26.0		
2000		16.0	11.0	18.5	20.3	19.2	24.1		
2100		15.0	11.1	17.5	19.4	18.8	22.2		
2200		12.0	11.0	16.1	18.8	18.6	20.3		
2300		10.1	11.0	15.3	18.7	18.3	18.5		
2400		12.8	10.5	11.2	18.8	18.8	17.9		

S-1 AIR TEMPERATURES (Continued)

Time	26/1	27/1	28/1	29/1	30/1	31/1	1/2	2/2	Remarks
0100		14.4	19.1	21.7	13.9	10.1	17.5	4.5	Start
0200		13.0	19.0	21.8	13.5	10.0	17.1	4.3	OT 1100±30/25
0300		12.0	18.3	21.6	12.8	9.7	16.0	4.0	TT 1100
0400		12.1	18.9	22.0	13.0	9.9	13.9	4.7	MT 27.0
0500		11.2	19.3	22.4	14.0	12.0	12.2	8.0	GT 28.0
0600		15.0	21.0	23.4	16.0	14.5	14.8	11.2	
0700		17.8	22.0	24.0	20.0	18.0	19.0	15.4	End
0800		19.8	23.2	25.4	25.1	21.8	19.2	17.8	OT NR
0900		22.0	23.7	26.7	29.0	22.6	20.0	19.9	TT 1300/2 AB
1000		25.0	24.4	27.3	29.8	23.0	21.1	22.0	MT NR
1100		26.7	24.9	27.5	31.0	23.4	22.2	23.8	GT NR
1200	27.8	27.1	25.0	28.8	31.5	24.0	22.0	24.3	
1300	27.0	26.5	25.0	29.1	32.8	24.1	21.5	25.2	Noted GT = 1.5 low
1400	26.0	26.0	25.3	29.0	33.0	24.2	20.8		at end of week
1500	24.9	27.0	25.0	29.0	32.9	24.1	20.2		
1600	25.3	24.3	24.7	25.1	34.8	23.3	20.0		
1700	25.3	24.0	24.0	25.5	34.0	23.1	20.0		
1800	24.1	21.8	24.2	23.5	28.3	23.2	20.3		
1900	22.5	20.2	23.8	23.0	22.5	21.5	20.4		
2000	21.9	19.9	22.3	18.2	18.1	21.0	16.2		
2100	21.5	18.8	22.0	13.8	13.0	20.2	9.0		
2200	19.9	19.0	21.9	12.4	10.1	19.8	5.7		
2300	17.7	19.0	21.9	13.0	8.7	18.9	4.1		
2400	16.4	19.2	21.6	13.9	9.9	18.2	2.1		

B. S-2

S-2 was occupied only intermittently during 1958, and the few weather records obtained there are held at the United States Weather Bureau National Weather Records Center, Asheville, North Carolina. Early in the year, Mr. J. Zimmerman, expedition meteorologist, substituted for the old totalizing anemometer a propeller and vane which were erected NE of the Jamesway hut and which recorded electrically inside the hut. The height above the surface of this propeller on 12 January 1959, was 2.45 m. On a visit in May, 1958, the glaciologists found that the thermograph shelter had been caught by the general S-2 drift and was only 3 cm above the surface. It was reinstalled several meters to the south with the base 1.45 m above the surface.

C. OCEANOGRAPHIC DATA

Observations of sea ice, tides, currents, and bottom sediments and organisms were made throughout 1958, by the Wilkes Station Scientific Leader, Dr. Willis Tressler (Tressler, 1960b). The paragraph below summarizes that part of his report which describes sea ice conditions, and includes additional observations by the glaciological party.

Daily observations of sea ice conditions in the base area were made from the aurora tower or nearby hills. The Hydrographic Office Shore Observer's Log was filled in each day. Sea ice movement was recorded by a number of time lapse movies taken throughout the year. Until the late fall all new ice in the local coves was broken out by repeated high winds. The new ice established itself permanently on 27 May. The thicknesses (cm) recorded near base were:

27 May	Started to freeze	8 July	76
9 June	35	11 July	79
11 June	38	8 August	103
21 June	53	25 August	103
25 June	61	16 September	127

From 16 September on, no increase in thickness was noted until the ice finally left the coves near base in December. The fast ice probably never reached Frazier Island. Breakup of most of the seaward ice occurred early in November, 2-1/2-months later than in 1957. However, south of the station and east of the outer islands the anchored fast ice held until at last early 1959. Both Ardery and Holl Islands were reached by weasel in December, and during that month several weasel journeys were made across the ice to Browning and Peterson Islands. By Christmas Day cracks in the ice were wide and slushy enough to discourage futher traffic. Similarly the fast ice north of the station, anchored among the presumably grounded icebergs west of Cape Folger, did not blow out, and it was still in position when the 1958 party left on 6 February 1958. During February, 1959, this northern fast ice was observed from a helicopter a few hundred feet above Cape Folger and the Balaena Islets, and stretched to the limit of vision in the NW.

VI. GLACIOLOGICAL OBSERVATIONS ON THE SURFACE

A. SURFACE FORMS (Hollin)

1. Radiation effects

a. Radiation hollows (Figs. 23 and 24)

These were the most striking radiation effects seen in the Wilkes area. They were found everywhere on the islands and on the ice sheet up to approximately 300 m. Regardless of relief, they were everywhere aligned strictly E-W, and were used at night for navigating overland between Haupt Nunatak and Clark Island. They appeared to form first in snow. Cronk noted that the first part of them to turn into ice was the lower side of each ridge (the roof of each hollow), and thought that the ice might be produced by heating in the hollow or by the re-freezing of melted water seeping down from above. Eventually each ridge turned completely into bubbly ice, with a relief somewhat less than that of the original snow ridges. Where they were not covered by autumn snow the ridges gradually disappeared during the winter, probably as a result of sublimation, and few of them survived until the following summer.

b. Firn pinnacles (Fig. 25)

These were observed on both the NE and SW slopes of drifts on Browning Island. No detailed observations of them were made, but they are probably a type of névé penitent. Their formation may owe something to the relative abundance of windblown dirt on Browning Island.

2. Wind effects

These have been loosely classified below. Effects (d), (e), and possibly (b) are constructional; the rest are erosional.

a. "Small pits"

W. Vickers (personal communication) has suggested that the small pits (several centimeters long and one centimeter or so deep) found in hard surfaces may be formed by the impact of fragments of windblown crust and by subsequent deflation.

b. Ripples (Fig. 26)

c. "Tiles" (Fig. 27)

These have the form of shallow escarpments, sometimes capped by a hard stratum or crust, and undercut by wind on the scarp slope. In plan they form lines of adjacent crescents, convex upwind.

d. Barchan-like forms

These were noted on the S-2 trail but they were not abundant, and their relief rarely exceeded a few tens of centimeters.

e. Linear dunes (Fig. 28)

These were noted on the 1958 traverse, had a normal orientation of 105°, and appeared to be laid down by blizzard winds. They may be related to the longitudinal dunes or seifs of sand deserts. Following deposition they appear to be cut into sastrugi by prevailing winds with a direction of 150° (Fig. 28).

f. Sastrugi (Fig. 29)

These had a maximum relief of one meter, but were normally less than half that height. Stronger winds seem to decrease their number but increase their height.

g. Wind scoops (Fig. 30)

Large scoops, hollows or moats adjacent to rock outcrops appeared to be maintained by wind rather than by the radiation often quoted as their cause. They persisted throughout the winter, when radiation was absent, and could be found on the south (shaded) side of outcrops.

3. Data from journeys

a. Journey to Cape Folger (26 August; abstracted from notes by Cronk)

The coastal cliffs are usually white (superimposed ice and frozen spray), but occasionally blue where recent calving has left glacial ice exposed. The drifts below the cliffs include fallen cornices, but rarely reach the level of the cliff top. For several hundred meters offshore the sea ice is quite smooth, and has little snow on it. Further out to sea the snow cover increases, and includes erosional forms aligned at right angles to the coast.

b. Journey to the Vanderford Glacier and Browning Island (3-7 March; abstracted from notes by Cronk)

On the journey out, there was much unconsolidated snow on the Ramp, apparently deposited by winds from the north. On the ice sheet old sastrugi showed as ridges through the new snow. The course followed was too near the coast, and crevasses were encountered, probably associated with the Peterson Glacier. The crevassed area had a surface of bare ice, but the crevasses themselves were bridged with snow. Further south a small area of perfectly clear blue ice was crossed. The ice had hoarfrost below and probably represented a refrozen wave of melted water. A few miles NE of Haupt Nunatak melt channels were encountered. Adjacent to Haupt Nunatak, NNW from it, is an area of boulders, gravel, and cryoconite holes which may represent melting out ground moraine.

On 5, 6, and 7 March, at Haupt Nunatak there was a strong wind (with blowing snow) from approximately ESE. The strongest wind, which made walking difficult, appeared to be confined to the line of the Vanderford Glacier, since little wind was noticed on Browning Island and on the ice sheet NE of Haupt Nunatak. Also, during this time, little wind was recorded at Wilkes Station. (Hollin: The whole experience of the 1958 traverse suggests that the Vanderford Glacier and perhaps the glaciers to the west of it provide a funnel for gravity winds which continue to blow strongly even when the air at Wilkes Station is quite calm.) The surface of the Vanderford Glacier was predominantly ice, or ice with a thin cover of hard snow, best tackled in crampons. A few crevasses were sounded, but none deeper than 30 m found. Between Haupt Nunatak and Browning Island there are some small crevasses of few cm wide. A (dry) melt stream 5 m wide was encountered in this area, and since it led to an enclosed basin it may have drained englacially. Other enclosed basins contained frozen lakes.

By the time of the return journey, most of the fresh snow on the ice sheet had blown away, consolidated or turned into ice. Radiation hollows in snow graded laterally into radiation hollows in ice. The return route crossed an area of basins and domes with small crevasses. Some small ice hillocks, up to 80 cm high, may have been associated with crevasses, but were not investigated. Some crevasses up to 1 m across were encountered in what was probably the upper part of the depression between Mitchell Island and Robinson Ridges.

c. Journeys on the S-2 trail (Hollin)

Descriptions of travelling conditions on 7 May; 14, 16, and 22 July; and 4 September, are held at The Ohio State University. Note that no snow storm ever seemed to cover the weasel tracks to S-2 completely; each storm would cover say 50% of the tracks. Eventually, of course, after several storms, any given set of tracks would be covered. But one implication of the incomplete cover is that probably no single snow stratum can be traced continuously in pits between S-2 and Base. The following detailed notes of surface forms were made, and give some idea of good travelling conditions in summer (usually better than in winter).

(i) <u>16 November (Directions are ±5°)</u>

<u>Mile 45</u> Parts of the surface crusted.
Tiles, relief 10 cm, convex towards 94°.

<u>Mile 40</u> Parts of the surface crusted.
Tiles, relief 10 cm, convex towards 100°.

Mile 35 — No crust visible.
Tiles, relief 15 cm, convex towards 102°.

Mile 30 — Visibility poor from here on, but there appears to be more soft new snow than at previous stops.
Tiles, convex towards 105°.

Mile 25 — More new snow. Relief generally 10 cm.
Tiles, sharply convex towards 92°. A few low sastrugi.

Mile 20 — Soft new snow. Relief less than 15 cm.
Visibility poor, but lineation of surface forms appears to be 93°.

Mile 15 — Soft new snow. Relief less than 10 cm.
Many small tiles of new snow, 20 cm across each crescent.

Mile 10 — Soft new snow.
Tiles convex towards 92° and 25 cm across.
Small pits elongated towards 82°.

S-1 — Subdued relief, generally less than 5 cm.
Small tiles and sastrugi. Lineation of surface forms 67°.

Below S-1 — Unusually soft snow.

(Note that the above directions are strongly suggestive of the action of katabatic winds, weakening perhaps as S-1 is approached.)

(ii) 7 January, 1959, (Directions ±9°)

S-1 — 5 cm of relatively new snow, with small pits elongated towards 76°, overlying older snow faintly pitted towards 96°.

Mile 10 — Faint tiles and small pits in new snow.
Lineation 96°, relief less than 8 cm.

Mile 15 — A few lineations towards 96°, almost obscured by currently falling snow flakes.

Mile 20 — Small pits 5 cm deep, elongated towards 96°.

Mile 25 — Various relief of 5 cm, lineated towards 101°.
Larger scale hummocks and hollows.

Mile 30 — A general surface crust.
Relief less than 8 cm, lineated towards 96°.
Larger scale hollows: quite bumpy.

Mile 35 As for Mile 30

Mile 37.5 A shiny surface hereabouts appears to be formed by a smooth crust, probably of melt origin.

Mile 40 Relief 10 cm, generally lineated towards 98°. Shallow barchan-like forms and sastrugi, all crusted and suggestive of variable wind directions.

Mile 45 Relief 10 cm, generally lineated towards 116°. Old barchan-like forms appear to be undergoing erosion into sastrugi. The crust seems thinner here.

For more detail on the trail surface see Section VI-B-5.

B. STAKE MEASUREMENTS AND ASSOCIATED OBSERVATIONS

1. Introduction

Stake readings for 1958, are presented below by areas. Unless otherwise mentioned, figures are in centimeters and were measured from the top of the stake to the snow surface. Small and narrow drifts a few cm high in the lee of the stakes themselves were ignored, and the measurements taken on the upwind side. If the stake was in a marked drift, such as a migrating barchan, this is mentioned. Observations should be accurate to less than 1 cm.

2. Accumulation on Clark Island and the Ramp (Hollin)

In November, 1958 before appreciable melting began, the total accumulation since the 1957-58 summer was measured in these areas. The new snow was sounded with a SIPRE one-inch drill until firn or ice was encountered. The readings are listed by regions, and represent snow depths in cm. The places and points mentioned are marked on the Northern Area map (Fig. 11).

a. (22 Nov.) At each surveyed point on the Ramp profile

These readings are shown graphically in Section II-B-9. Their average is 56 cm.

b. (22 Nov.) From C7 to Base, at every 0.1 mile by weasel odometer:

67, 88, 40, 33, 100, 63 (near C8), 46, 27, 16, 32 (hill close to point 2 of Topographic Survey II-B-6), 38 (valley nearby), > 105 (only one length of drill available), 49, 86, 105, 89. Average 61.5 cm.

c. (24 Nov.)

Every 0.1 mile by odometer, from Base, NE through the main Clark Island depression to the embayment on the N coast, up to the Moraine via the west end of lake "A", diagonally down to and through the Corridor.

0, 41, 14, 3 (new snow on lake ice), 3 (ditto), 30, 34, 82, 103, 42, 21, 63, 90, 110, 30, 57, 63, 39, 3 (new snow on lake ice), 3 (new snow on sea ice), 41, 20, 54 (just below the shear moraine), 59, 69, 71, 46, 58, 49, 71 (entering the Corridor), 47, 82, 85, 115, 57 (in a slight hollow in the Corridor), 48, 78, 81 (end of Corridor). Average depth at points on the Ramp 49 cm; at points on Clark Island 50 cm.

d. (24 Nov.) Close to the lower Grinnell core.
One measurement of 75 cm.

These figures show greater accumulation in these areas than on the ice sheet, and demonstrate the effects of topographic irregularity and friction on wind speed and snow transporting power. The particularly small figures for the level and smooth lake and sea ice emphasize this point. Presumably in this area the gravity winds of the ice sheet decelerate and drop part of their load of snow. With one exception, these measurements were made on the perennial snow and ice patches of the Ramp and Clark Island, and as such do not represent an average for the whole of those areas. Rock patches were normally kept free of snow by wind and by the effects of low albedo. At the beginning of the summer of 1958-59 they had a negligible accumulation, which reduces considerably the average accumulation for the whole of Clark Island and the Ramp. However, averages for the snow and ice patches alone are needed for a discussion of their history and persistence.

3. The ice sheet northeast of Clark Island
(Robertson, Cronk)

The position of these stakes and the difficulty of identifying them in December are described in Section III-D. The abbreviations used are described in the following section (VI-B-4). "Ir" means melted ice with the crystal boundaries showing.

	10 Feb. 1958		24 Dec. 1959		% of surrounding area covered by			
Stake	Reading	Surface at stake	Reading	Surface at stake	Sg	Ir	I	Remarks
431	76	Sfr						
432	76	"						
433	74	"	69.5?	Is	30	-	70	Stakes not positively identified as 433-6. Probably as listed but possibly any before 437 so long as in this order.
434	72	"	59?	S (slush)	40	-	60	
435	73	"	22?	Sg	80	-	20	Sg is sticky
436	77	"		Ir	20	60	20	Melted out. I may be this or last season's.
437	100	"	110	I (slush)	30	60	10	
438	72	"	40?	Sg	50	25	25	Stakes not positively identified as 438 + 440. Probably as listed but could include 439, so long as in this order. Sg is sticky.
439	76	"						
440	72	"	41.5?		80	15	5	
441	76	Im	56.5	Sg	100	-	-	
442	84	Sfr	60	Sg	100	-	-	
443	75	"	77	Sg	80	10	10	
444	69	Im			20	70	10	Melted out
445	77	Sfr	69	Ir	10	80	10	
446	75	Sfr	69?	Sg + Ir	20	60	20	Almost certainly 446.
447	104	"						447-9 disappeared or unidentified. One appeared to have melted out in the previous fall.
448	98	Im						
449	101	Sfr						
450	107	Im	92?					Almost certainly 450
451	100	"	105?	Ir				Probably 451
452	102	I	86?	Ir	10	90	-	Possibly 452
453	100	Sfr or Ig						
454	100	I	64?	Sg	50	30	20	Possibly 454. Definitely not 455. Sg is sticky.
455	98	I						

4. Base to Mile 8 (Km 13)
(Cronk, Hollin)

a. Stake measurements

The position of these stakes, which lie on Clark Island, the Ramp and the ice sheet up to 380 m, is shown on the Northern Area map (Fig. 11). With the exception of the cross-profiles at 262 m and 380 m the stakes lie on or close to the first 13 km of the S-2 trail, and cover the ablation and superimposed ice accumulation zones. Those on Clark Island and the Ramp are in areas where local topography might be expected to cause widely varying readings. Those on the ice sheet, however, are inserted in what is an extremely regular surface, except in the area of Stake 402 and (to a lesser extent) 403, where the trail passes over an undulation which rises 5 m or so above the generally convex profile of the ice sheet, and which is obviously more wind-swept than the rest of the area.

These stakes were originally inserted in the Antarctic spring of 1957, and readings on them are listed in the Report for 1957 under the heading "Ramp Stakes". Most of them were 1-1/2-inch diameter half-rounds inserted approximately half a meter into the ice. This was not enough to hold them in the unexpectedly heavy thawing during the summer, and eventually all the original stakes melted out, except for the bamboos at F2, BF1, BF2, and 430. These four stakes give continuous readings from 1957 to 1958. On 5 February 1958 the old melted half-rounds were replaced by new split bamboos inserted to one meter, and readings on the half-rounds were discontinued. Many of these new stakes in their turn melted out, but readings on them were commenced as they froze in again and, as the data shows, by 24 February all were frozen in and recording. Thereafter, continuous records are available until the departure of the 1958 party in February, 1959. Note that, in addition to the four stakes mentioned as giving continuous values through the 1957-58 summer, stakes 419, 421, and 423 were not melted out at the time of their last measurement on 3 February 1958. If an ablation value is assumed for the two days until 5 February (for which day readings on the new stakes at these points are available), then continuous values of accumulation or ablation can be calculated for these three additional localities.

At the end of April, 1958, stake 430 was blown down, and the opportunity was taken to emplace a new series of stakes on Clark Island and the Ramp, along the general line of the trail below stake 402. Again these are shown on the map, and the reference in Section VI-B-2 concerning the effect of topography should be noted. Stake 00 lies in the level area close to the Base rubbish dump; 01 is on the slope of the perennial drift to the north of the first wide plain encountered on the trail; 02 is on the biggest and flattest snow and ice plain on Clark Island; 05 is in the lee of the main moraine; and 06 is in the hollow, usually occupied by a puddle in summer, just above the moraine. 06 was used in Movement survey III-F.

During the winter the stakes 01, 403, BF2, 424, 426, 425, 427, 428, and 429 appeared to be in danger of submergence by snow, and additional taller stakes were drilled to a depth of two meters at these positions. These new stakes were usually inserted a meter or so from the old ones, and the readings on them are recorded in brackets. The new stakes at 01, 403, and 429 are measured in the normal manner from the top of the stake, but the others from a notch cut at the time of installation to agree with the height of the old stake. In the case of these others then, the difference in readings between the old and the new stakes will serve as an index of the unevenness of the local snow topography. The new stake at 403 is the northernmost of three, and was used in Movement survey III-F. (The central stake is the 5 February insert, and the southern one the 1957 half-round).

During the summer of 1958-59, the only one of the new stakes which melted out was 402. Its melting was anticipated, and the readings were transferred beforehand to the nearby "superimposed ice stakes" A and B (see readings for 15 December) and to Movement survey III-F stake M3 (see readings for 29 December). By 22 December 1958, a few bamboos were beginning to lean appreciably, and this is mentioned in the data whenever necessary. Stakes were inserted into the ice with the SIPRE one inch auger, which frequently jammed badly below one meter. A portable "Cobra" rock drill, available at Base, was experimented with but froze in at small depths.

b. Associated observations

Particularly during the winter months there was no time on the day of measurements to collect such ideally desirable information as exact descriptions ofthe snow surface and stratigraphy at each stake. However, just by looking around them, observers were able to record brief descriptions of surfaces, unusual phenomena, etc.; consequently a considerable body of supplementary information is presented with the stake readings. It should be remembered however that this supplementary information (i) is quite arbitrary; e.g., if hoarfrost is recorded only at stake 402 this does not mean that there was no hoarfrost at any other stake and (ii) contains a strong personal factor, since five observers (including two non-glaciologists for the period 17 September - 17 November) were involved; e.g., one man's "Sg" might be another man's "Sfr" (see the abbreviations below). In most cases the observer was Cronk, and the original data is in his notebooks; the exceptions are noted.

For most weeks there have been recorded the type of surface at the stake and the percentage of the surrounding area covered by various surfaces. By "surrounding area" is usually meant the area within 100 meters or so of the stake. Surfaces are described by the abbreviations listed below. These are listed roughly in order of increasing density and change from snow to ice. This classification of surfaces was an empirical development by the observers and has no theoretical basis.

S Snow, unspecified; could be any of the S headings.

Sf Fresh snow.

Sb Windblown snow with rounded grains, but quite loose and not built into features such as barchans.

Sd Wind worked snow. Drifted and beginning to consolidate Generally recent and included small barchans.

Se Erosion forms visible. Incipient sastrugi.

Sp Fine grained and well consolidated.

Scr Fine grained, with an unspecified crust or hard layer, which could usually be pierced by a rod or foot.

Sci As above, but with a noticeably icy or glazed crust, sometimes recorded as "sum reflecting".

Sg Coarse snow. Grain size increasing.

Sfr Frozen snow, intermediate between Sg and Si.

Si Icy snow. Coarse and well cemented. Grains would separate only if kicked.

Is Ice which appeared to have been formed by the welding of a new snow cover onto an old ice surface. It was typically seen at the boundary of a new drift and an old ice surface: each day more of the drift was turned into ice, until a new accretion of superimposed ice was left with the shape of a drift. The process was most marked in autumn and may have involved both sublimation and melting. The ice formed in this way was generally bubblier and whiter than that below, but could be distinguished definitely only by its relief.

Im Sheets of generally bubble-free ice, probably formed by the outflow of melt water from the snow pack.

Io Old superimposed or glacial ice.

I Ice, unspecified; could be any of the I headings.

In these abbreviations a minus sign denotes a weak phenomenon; e.g., Sp- is only slightly packed and a plus sign or an underlining denotes a strong phenomenon. It must be stressed again that the above abbreviations are descriptive rather than precise, and that different observers might easily assign the same surface to different categories. The depth of Sf is often listed separately in the supplementary information, since this relatively rare deposit of unblown 0.2 density snow usually blew away at the first wind and therefore gives misleading ablation figures. "Radiation hollows" are described in Section VI-A-1. "BF1 and BF2" are abbreviations for Black flag 1 and Black flag 2, installed in 1957. "F2B" in the weekly data is actually F2 (a flag just north of F2B--see Fig. 11).

c. Results

Although a more rigorous analysis of the stake measurements will be offered later (combining data from sections V, VII and "Summer" of this report), some first conclusions show quite clearly. Before they are discussed it will be useful to refer to the average state of the glacial economy in this area, as suggested by the stratigraphic and other observations described in Section VII. These observations show that in an average year the lower limit of what may be called the firn zone of accumulation lies at an elevation of approximately 345 m, not far from the upper cross-profile of the stakes under discussion. Below this elevation all the accumulation available at the beginning of each summer is transformed into superimposed ice. That is to say, the accumulation is totally melted but, because of the low surface angle hereabouts and because of the cold ice below, the melt water does not have time to drain away before it refreezes as a layer of superimposed ice. The lower limit of the superimposed ice zone of accumulation is harder to determine stratigraphically because of the difficulty of distinguishing accumulating superimposed ice from ablating superimposed ice. Probably the only conclusive way of distinguishing between these two would be by a tritium or similar dating of the ice. Tentatively, the lower limit of the superimposed ice zone of accumulation on the S-2 trail appears to be at about 230 m elevation, but it may be much higher. However, below 230 m one is definitely in the zone of ablation, as shown by phenomena such as melt stream channels and strongly preferred crystal orientations in the ice. In the lee of the shear moraine, at about 140 m, there may be small equilibrium zones fed by blowing snow dumped by decelerating katabatic winds, but in general the ablation zone continues down to sea level. All the above has been discussed in more detail elsewhere (Hollin, 1959), and is treated further in Section VII-A-10-a. Turning from the average situation revealed by stratigraphic studies, the particular situation revealed by the stake measurements of 1958, is outlined below:

(i) The year began in January and February with melting on what was probably an average scale. Streams made travel difficult below 150 m, and stake 430 recorded 50 cm of ablation, which probably included melting, evaporation, and sublimation.

(ii) A marked feature of the autumn stake measurements is the evidence they offer of intensive sublimation at quite low air temperatures. For example, between 3 March and 21 April, stake 403 records the removal of 4 cm of ice and stake 407, 5.5 cm. This lowering of the ice surface is unlikely to be caused by deflation, since observations at both Wilkes and (by the Soviet Antarctic Expedition) at Mirny show that even thin snow crusts are effective shields in this respect. Moreover, these high figures for sublimation have been confirmed by observations in similar localities at both Mirny and Mawson. Sublimation from snow surfaces is probably even greater than from ice, but harder to distinguish from deflation as far as stake measurements are concerned.

(iii) Accumulation appears to have been relatively small during the first half of 1958. This could be the result either of meteorological conditions or of the fact that snow grains blown into this area could not find a lodgment on the smooth ice of the superimposed ice and ablation zones. It is of interest that a "drought" in early 1958 has been reported for Mirny also (Tolstikov, 1958).

(iv) Ablation in the summer of 1958-59 was far less than in that of 1957-58 (and of 1956-57, according to R. Cameron). Few streams were observed, and the whole area down to sea level remained in the accumulation zone. Stakes 402 to 429 show for the period 24 February 1958 to 2 February 1959 an average net gain of 26 cm snow (10 cm of water, assuming a snow density of 0.38 and assuming that the sublimation of ice below the snow or the accumulation of superimposed ice below the snow is negligible). Note that the average temperature at Wilkes Station in 1958 was more than 2°C lower than that in 1957, and that this cold persisted into the summer of 1958-59, and was presumably responsible for the reduction in ablation. Again, the relative cold of the 1958-59 summer was noted at Mirny also. (Savelyev, 1959, and Anonymous, 1959.)

The actual stake measurements and associated observation between Base and Mile 8 are presented by weeks in the following pages. Considerable assistance with these measurements was given by Chief J. Lynsky and Fr. H. Birkenhauer, S. J.

27 January 1958 (See introduction to this section)

Stake	Reading	Surface at Stake	Remarks
401		Sfr	Melted out
402		Sfr	Melted out
403		Si	Melted out
404		Si	Melted out
405		Si	Melted out
406		I	Melted out
407		Si	Melted out
408		Si	Melted out
409		Si	Melted out
410		Si	Melted out
411		Si	Melted out
412		I	Melted out. Melt water on surface
413		I	Melted out
414		Sg	Melted out
415		Sg	Melted out
F2	113.5	Sg	
416		Sg	Melted out
BF1	85	Sg	
417	91.5?	Sg	Possibly melted out
BF2	89	Sg	
418	89 ?	Sg	Possibly melted out
419	83.5	Sg	
420	93 ?	Sg	Possibly melted out
421	68	Sg	
422		Si	Melted out
423	81	Sg	
424		Si	Melted out
426		I	Melted out
425		Sg	Melted out
427	52	Sg	
428		I	Melted out
429	43	I	
430	131.5	Sg	

3 February (See introduction to this section)

Stake	Reading	Surface at Stake	Remarks
401		Si	Melted out
402		Si	Melted out
403		Si	Melted out
404		Si	Melted out
405		Si	Melted out
406		Si	Melted out
407		Si	Melted out
408		Si	Melted out
409		Si	Melted out
410		Sf on Si on I	Melted out
411		Thin Si on I	Melted out
412		Thin Si on I	Melted out
413		I, probably Io	Melted out
414		Io with slight Sf	Melted out
415		Sf on I	Melted out
F2	114	Sf on I	
416		Sf on I	Melted out
BF1	85	Sf on I	
417	90?	Sf on Si	Possibly melted out, probably good
BF2	92	Sf on Si	
418	88?	Sf on Si	Possibly melted out
419	85	Sf on Si	
420	90?	Sf on Si	Possibly melted out
421	69	Sf on Si	
422		Io	Melted out
423	81	Sfr	
424		Sf on Sfr	Melted out
426		Sf on Sfr	Melted out
425		Sf on Sfr	Melted out
427	50?	Sfr	Possibly melted out
428		Im	Melted out
429	43	Io	
430	134	Si	

5 February (See introduction to this section)

Stake	Reading	Remarks
401		Eliminated: too close to 402
402		Melted out by next week
403		Melted out by next week
404		Melted out by next week
405		Melted out by next week
406		Melted out by next week
407		Melted out by next week
408		Melted out by next week
409		Melted out by next week
410		Melted out by next week
411		Melted out by next week
412		Melted out by next week
413		Melted out by next week
414	100.5	
415	104.5	
416	105.5	
417	103	
418	100.5	
419	101	
420	97.5	
421	96	
422	104.5	Melted later but figures appear reasonable
423	102	
424		Melted out by next week
426		Melted out by next week
427		Melted out by next week
428		Melted out by next week
429		Melted out by next week

See introduction to this section and note that these are new stakes.

10 February (See introduction to this section)

Stake	Reading	Surface at Stake	Estimated Average S Depths to I cms	Remarks
402		Si	Remnants	I is Im 1 cm thick with crysta boundaries below visible through it
403		Si	Approx. 6	Melted out
404		Si	1-3	Melted out
405		Si	0-2	Melted out
406		Si	1-3	Melted out
407		Si	1-3	Melted out
408		Si	0-2	Melted out
409		Si	0-3	Melted out
410	90.5?	Im and Io		Melted but figures look reason able
411		Si	0-2	Melted out
412		Im over S		Melted out
413		Im over S		
414	102	Sfr	0-3	Estimated grain size < 1 mm. Radiation hollows in ice under snow
415	103.5	Sfr		Estimated grain size < 1 mm
F2	114	Sfr	0-3	Estimated grain size < 1 mm
416	106	Sfr	0-3	Fine grain
BF1	86	Sfr	0-3	Fine grain
417	102.5	Sfr	0-3	Fine grain
BF2	91.5	Sfr	0-3	Fine grain. Some I near, probably Im
418	99.5	Sfr		Fine grain
419	100.5	Sfr	3-6	Fine grain
420	97.5	Sfr	3-6	Fine grain
421	96.5	Sfr		Fine grain
422	104	I		Melted round stake, but this still firm and the reading looks reasonable
423	103	Sfr		Fine grain. A large area nea here is mostly ice; snow features grade into ice
424		I		Melted out. V coarse ice, rather like corn snow bonded
426		I		Melted out
425		I		Melted out. V coarse ice. Barchan grading from Si on outside to I inside
427		I		Coarse granular
428		I		Coarse granular and Im
429		I		Coarse granular and Im
430	134	Sg		

See introduction to this section and note that all except F2, BF1, BF and 430 are new stakes inserted only on 5 February.

17 February (See introduction to this section)

Stake	Reading	Surface at Stake	Estimated Average S Depths to I cms	Remarks
402	92	Si	9	The Ramp below here has both new Im and new S in small drifts
403	95	Si	3-6	Some Sf. Earlier Sf drifted into hollows has now melted out
404	92	Si	1-3 Sf	Snow on Im is changing to I
405	87	I	0-2 Sf	Sf in long sastrugi
406	86	I	0-2 Sf	Sf in long sastrugi
407	80	Si	0-2	Drift to leeward changing to I
408	86	I with Sf		
409	93.5	Si with 2 cms Sf		
410	82	I with Sd		
411	82	I with Sd		Areas of semi-transparent I with crystal boundaries below visible
412	77.5	Is		Probably superimposed
413	77	Is on old Im		
414	102	I and Sd		
415	104.5	Sf	0-2	Long sastrugi
F2	112.5	I and Si		
416	106	Si	0-3	Drifts
BF1	85	Sd		Fine grain, probably $<$ 1 mm
417	103	Sd	0-3	Fine grain
BF2	92	Sd		Fine grain
418	99	S		Fine grain
419	97.5	Sd		Fine grain
420	98.5	Sd		Fine grain
421	96.5	S		Fine grain
422	104	I		Bubbly, with radiation hollows
423	102.5	Sf		9 cms of fine grained Sf
424	83	I		Slight drifts
426	72	I		Melted out but reading appears reasonable. Fresh snow hereabouts drifted and rippled by wind
425	74	I		Some Si with wind ripples on surface
427	66.5	I and Sfr		Melted out but reading appears reasonable
428	79	Si	0-2	Sf locally
429	83	Si and Sd	1-3	
430	135.5	Si		

This is approximately the end of the strong melt season, though there is still a long period of little accumulation. The two stakes recorded as melted out are actually frozen in at the bottom of their holes. After 17 February there was no more trouble due to the melting and sinking of stakes.

24 February (See introduction to this section)

Stake	Reading	Surface at Stake	Remarks
402	94	I	Breaks apart easily into crystals
403	97.5	I(s?)	
404	95	I(s?)	Slight radiation hollows
405	88		
406	87.5	Is	
407	81.5	Is	Drift to leeward now completely turned to I
408	87	Is	
409	94	Is	
410	83.5	Io	
411	83	Is	
412	79	Im	Boundaries of horizontally elongated crystals show on Im surface
413	78	Im	Boundaries as above. Radiation hollows in Si are well rounded
414	103	I and Si	More I than S
415	106	Si and I	More S than I
F2	115	Si and I	More S than I
416	107	Si and I	Fairly large patches of S. Below this the area is mostly ice
BF1	87	Si	Very icy
417	104.5	Si and I	Very icy
BF2	92	Si	Predominantly S, but ice patch with radiation hollows between BF2 and 418
418	101.5	Si	
419	101.5	Si	Radiation hollows
420	98.5	Si	I patches extend still further inland
421	97/98	Si	Original record blurred
422	104.5	I	At edge of large ice patch extending to south. Some drifts
423	104	Si	Very icy
424	84	I	Some snow features remaining in ice; shows crystal patterns
426	74	I	Some drifts and some drifts partly turned to ice
425	75	I	
427	66.5	I	
428	84	Is	
429	84.5	Is	
430	137.5	I	

Much more ice on the Ramp this week, both smooth Im areas, and I that shows snow features, i.e. Is.

3 March

Stake	Reading	Surface at Stake	Surface in Area Surrounding	Estimated Average S Depths to I cms	Remarks
402	95	I	Sd		
403	97	I	Sd	0- 5	
404	95.5	I	Sd		
405	84.5	I		6	Drift in lee of stake
406	86	I			Drift in lee of stake. Surface of ice suggests melted out bubbles, i.e. ablation of ice
407	80.5	I		0- 2	Drift in lee of stake
408	85.5	I		0- 2	Drift in lee of stake
409	94	I		0- 2	Drift in lee of stake
410	84	I			Drift in lee of stake; ice almost clear
411	81	Sd		0- 5	Snow has filled most hollows and shows some signs of wind pitting
412	79	I		0- 6	Drift in lee of stake
413	78	I/Is			Drift in lee of stake
414	103	I	Si and Sd		
415	105	Sd		3	Snow slightly packed and pitted by wind
F2	115	I	Si-		
416	103	Sd		2- 6	
BF1	83.5	Si and Sd			
417	105	Si and Sd			
BF2	90	Si and Sd			
418	101.5	Si and Sd			
419	99	Sf		9	
420	97.5	Sf		3	Drift in lee of stake
421	95	Sd on Si		6	
422	101	I			Drift in lee of stake
423	98	Sd on Si and I		9-12	
424	85	I			Slight drift in lee of stake
426	71.5	Sd		6	
425	74	I		0- 3	Drift in lee of stake
427	65	I			Drift in lee of stake
428	83	I			Drift in lee of stake
429	78	I	Sd on I	8	
430	137.5	I	Sf		

Wind directly down slope, approximately easterly.

Frequent drifts downwind from stakes.

Stake 408 wind blasted.

Stake	Reading	Surface at Stake	Surface in Area Surrounding	Remarks
402	96	Is?		
403	98	Is?		
404	96	Is?	Sd	
405	87			Stake in low drift
406	89	Is?		
407	81.5	Is?		Ice chips from excavation la week show little change
408	87	Sp		Packed layer is thin
409	95	Is? and Sp		
410	84.5	I		
411	85	I	Sp	
412	79	Im on S		Boundary melt has delineated long crystals
413	87.5	I		Boundary melt has delineated long crystals. **Possibly** 77.5?
414	103	∠1 cm Sf on I with radiation hollows		Some drifts of old Sp
415	106	Sf on I with radiation hollows		
F2	117	I with Sf (powder)		
416	103	Sf (5 cms)		
BF1	85.5	Sg with Sf (powder)		
417	104.5	Sf on I		Area covered with Sf and Sd with some old Sp and Si
BF2	89.5	2 - 3 cms Sf on Si		
418	100.5	3 - 8 cms Sf on Sp		
419	101	Sf on Sp		Some Sp—
420	96.5	Sf and Sp		Sp is from last week's storm
421	95.5	2 - 3 cms Sf on Sp		
422	102	Sf on I		
423	101	3 cms Sf on I		
424	94.5?	I with crystals as at 412		Misread for 84.5?
426	71.5	3 cms Sp on I		
425	75	I		
427	67	S (powder) on I		
428	83.5	S (powder) on I		
429	80	S (powder) on I		
430	139	I with Si		

"Is?" was thought at the time of observation to be "Is" as defined in the introduction to this section. Later, however, it was decided that the bubble structure of this ice represented more probably the melting ou of old ice.

"S (powder)" is usually Sf but may include drifted snow.

17 March

Stake	Reading	Surface at Stake	% of Surrounding Area Snow Covered	Remarks
402	97	I	5	
403	Missed			
404	(96)	Sf		
405	(93)?	Sf	70	Possibly 83?
406	(90)	I	60	
407	(91)		80	**Possibly 81?**
408	(87)		70	
409	(96)?		85	Figure doubtful; original data missing
410	(95)	I	70	Possibly 85?
411	82	Sf	85	
412	80	Sf	90	
413	79	Sf	95	
414	97	Sf	90	
415	106	Sf	95	
416	104	Sf	99	
BF1	81	Sf	99	
417	102	Sf	99	
BF2	84	Sf	100	From BF2 to 423 patches of Is
418	100	Sf	100	
419	98	Sf	100	
420	96	Sf	100	
421	96	Sf	100	
422	96	Sf	100	Hummocky
423	95	Sf	100	
424	86	I	50	
426	71	S	50	
425	75	S	60	
427	68	I	70	
428	82	Sf	80	
429	77	Sf	90	Hummocky

Figures thus (96) may not apply to correct stake numbers.

Original data in Hollin's notebook and in general notes.

24 March

Stake	Reading	Surface at Stake	Remarks
402	97	I	
403	99	I	
404	97	I	
405	89	I	
406	90	I	
407	83	I	
408	88	I	
409	95	I	Small patches of very hard Sp
410	85	I	Small drift at stake
411	85	I	< 10 per cent of area is Sd
412	80	I	
413	79	I	
414	103.5	I	
415	106.5	I	Approximately 10 per cent of area is S in patches
F2	116.5	I	
416	105.5	I	Approximately 20 per cent of area is Sd
BF1	88	I and Si	
417	105	I and Si	Some patches of Sp
BF2	92.5	I and Sp	
418	101.5	I and Si	Some Sp
419	101	Si and Sp	
420	99	I and Si	Approximately 60 per cent of area is Sp
421	97.5	I and Si	
422	105	I	Smooth
423	104	Si and Sp	
424	96	I	**Possibly** 86?
426	76	I	
425	76	I	
427	68	I	
428	85.5	I	
429	85	I	
430	142		

These observations followed several days of high winds which had removed most of the Sf and eroded parts of old Sp drifts. Some melting had probably occurred. Above the moraine there was considerable ice all the way to the upper profile. This ice included much hard and very bubbly white colored Is, and possibly thick Im colored white by the firn and depth hoar beneath. Below the moraine many of the empty stream beds are recorded as filled with ice, but what type of ice was not recorded. (At this time of year these empty stream beds were still a big obstacle to travel in the lower part of the Ramp.) This is one of the iciest weeks in the record.

31 March

Stake	Reading	Surface at Stake	% of Surrounding Area Snow Covered	Remarks
402	97	I	5	S largely in stream valleys
403	99	I	2	
404	97	I	1	
405	90	I	2	
406	90	I	2	
407	83	I	3	
408	88	I	3	
409	95.5	I	5	Patches of Sd
410	86	I		
411	85	I	3	
412	80	I		Large areas of Im with crystal boundaries showing and hoar crystals below, all on top of I with apparently small crystals
413	73	Im	5-10	
414	105.5	Im	5	
415	107	I	8	Very icy but 0 - 2 cms Sg locally
F2	117.5	I	50	
416	107.5	I	80	80 includes white Is
BF1	86.5	Si	60	60 includes white Is
417	105			
BF2	103	Si		Possibly 93?
418	102	Si	80	80 includes white Is
419	102.5	Si	95	Small patches of Sp
420	100	Si	90	Uphill from here an area with 20 per cent Im and Sd/Sfr
421	98	Si	100	
422	104.5	I	50	
423	104.5	Si	80	Some Sp
424	85	I	3	
426	76	I	3	
425	75.5	I	3	
427	68	I	2	
428	85.5	I	2	
429	85	I	2	
430	142.5	I		

The Ramp had a few wind packed drifts but otherwise was icy and little different from the previous week. Between 402 and 406 stream depressions showed well. At 410 ice chips from 5 days before were bonded together and thinned on the edges. Between 418 and 420 alternate patches of blue ice and Si, elongated in the direction of slope, suggest incipient stream flow during the summer.

7 April

Stake	Reading	Surface at Stake	% of Surrounding Area Covered by: S	I	Si	Remarks
402	92.5	S	5		95	S is in gullies
403	100	Is	15		85	S is in gullies
404	95	S	20	5	75	Much Im in sheets between 404 and 405
405	89.5	Si	5	5	90	
406	91	Si	5	5	90	
407	85	Si	5	5	90	
408	88	Si	15	5	80	
409	96	Si	10	5	85	
410	85.5	I	10	30	60	
411	86	Si	10	1	89	
412	81	Si	10	45	45	
413	80	Si	10	20	70	
414	104.5	Si	5	40	45	Radiation hollows
415	107.5	Si	5	85	10	
416	107.5	Si	10	5	85	S in depression to northwest
417	101.5	S	45	10	45	
BF2	93.5	S	90		10	I further inland
418	102.5	S	100			S nearly Is
419	103	S	95	5		S in all stages to Is
420	100	S	100			S turning to Is
421	98.5	S	100			I area inland
422	115.5	I	15	80	5	Mistake for 105.5?
423	104	S	100			S is icy on surface but probably plain S beneath
424	87	Si	5	95 I and Si together		
426	77	Si	5	95 I and Si together		
425	76.5	Si	5	95 I and Si together		
427	68.5	Si	10	90 I and Si together		
428	86	Si		50	50	
429	86	Si	5	5	90	
430	141.8	I	33.3	33.3	33.3	

In the above S is usually Sf, perhaps from several snowfalls but little metamorphosed; I is often Im; and Si has been used for anything between these extremes.

On 11 April, Clark Island was at its iciest yet. In these conditions it was often difficult to tow loads over the trail up to the moraine, although with patience a feasible route could always be found.

Original data in Hollin's notebooks.

On 3 April, I noted 43 miles from S-2.

14 April

Stake	Reading	Surface at Stake	% of Surrounding Area Covered by: S	I	Si	Remarks
402	96	S	10	10	80	
403	100	Si	10	5	85	
404	97	S	10	5	85	
405	91	Si	5		95	Si is quite icy. Some I in little ripples
406	91	Si	10		90	Si is quite icy. Some I in little ripples
407	85	Si	5	15	80	
408	89	Si	10	5	85	
409	98	Si	20	20	60	
410	87	I	5	10	85	
411	86	Si	15	15	70	
412	80	I	10	45	45	Downhill from 412 fresh drifts are from NNE
413	81	S	15	15	70	Uphill from 413 fresh drifts are from ESE
414	104	I	10	60	30	
415	106	Si	20	50	30	
416	108	Si	30	70 I and Si		Snowy hollow uphill
417	103	S	50	50 I and Si		
BF2	93	Si	50	50 I and Si		
418	105	Si	50	50 I and Si		
419	104	S	50	50 I and Si		
420	101	Si	60	40 I and Si		
421	99	S	70	30 I and Si		
422	101	S	15	70 I and Si mostly I		
423	105	Si	Close mixture of S, I and Si			
424	88	Si	5	5	90	
426	78	Si	20	20	60	
425	77	Si	10		90	
427	69		20		80	
428	86	Si	5	15	80	
429	86	Si	10	5	85	
430	132?		20	80 I and Si		Mistake for 142?

S, I and Si have the same meaning as for 7 April.

Between 402 and 404 a new variety of Si: small ridges parallel to the contours, icy on the upwind side and drifted on the downwind side.

Note that looking into the sun often gives a false impression of I, probably from crusts.

Original data in Hollin's notebook.

21 April

Stake	Reading	Surface at Stake	% of Surrounding Area Covered by: S	I	Si	Remarks
402	95.5	S	10		90	
403	101	Si	15		85	
404	96.5	S	25		75	
405	91	Si	10		90	
406	91	Si	20		80	
407	86	Si	15		85	
408	89.5	Si	20		80	
409	98	Si	20		80	
410	86	I	20	30	50	
411	86	Si	25		75	
412	82	Si	20	20	60	
413	80.5	Si	20	40	40	
414	105.5	I	30	20	50	
415	108	Si	20	20	60	
F2	117	Si	30	10	60	
416	108.5	Si	60	20	20	
BF2	93.5	S	50	50		
418	104	S	45	10	45	S and Si not differentiated i.e. 90 per cent not I but unspecified
419	103	Si	50		50	
420	100.5	S	50		50	
421	99.5	Si	50		50	As for 418 but 100 per cent
422	102.5	Sd	25	75 I and Si		
423	104.5	Si	50		50	As for 421
424	88	Si	10	90 I and Si		
426	73	S	5	95 I and Si		
425	77	I	10	90 I and Si		
427	69	I	20	80 I and Si		
428	87	Si	10	90 I and Si		
429	87	Si	10	90 I and Si		
430	140	I	30	30	40	

S, I and Si have the same meaning as for 7 April.

Si includes the ice and snow ridges described for 14 April.

Original data in Hollin's notebook.

28 April

Stake	Reading	Surface Near Stake	Average Depth of Sf Near Stake cms	Remarks
402	96.5	Sf and I		
403	100.5	Sf and I		
404	94	Sf on I	0- 2	At 404, 405, 406 Sf is mixed with Sfr
405	90	Sf on I	0- 2	
406	90	Sf on I	0- 1	
407	79.5	Sf(d) on I	4	
408	83.5	Sf on I	9	
409	96	Sf on I	0- 1/2	
410	82	Sf on I	0- 3	
411	85.5	Sf on I	5	
412	79	Sf	0- 1	
413	79	Sf		
414	104.5	Sf on I	0- 2	
415	108.5	Sf on I	0- 2	
416	107.5	Sf on I	0- 1/2	
BF1	89	Sf on I	1	
417	101	Sf on I		
BF2	97 ?	Sf on I	0-10	Misreading for 87?

Many new drifts on Clark Island following storm, which also blew down Stake 430.

Remainder of stakes could not be reached because of blowing snow.

5 May

Stake	Reading	Surface at Stake	Average Depth of Sf Near Stake cms	Remarks
402	94	Sf	3	
403	98	Sf	3	
404	93	Sf	3	
405	89	Sf	3	
406	89	Sf	3	
407	83	Sf	3	
408	87	Sf	2	
409	86?	Sf	3	Mistake for 96?
410	84	Sf	2	
411	84	Sf	2	
412	79	Sf	2	
413	78	Sf	2	
414	98	Sf	2	
415	106	Sf	1	
416	103	Sf	4	
417	99	Sf	3	
BF2	122	Sf	3	
418	96	Sf	3	
419	100	Sf	3	
420	98	Sf	2	
421	97	Sf	1	
422	95	Sf	2	
423	103	Sf	2	
424	84	Sf	2	
426	75	Sf	2 or 3	
425	75	Sf	2 or 3	
427	61	Sf	5	
428	69?	Sf	5	Mistake for 79?
429	84	Sf	3	

Original data in Robertson's notebooks.

12 May

Stake	Reading	Surface Near Stake	Average Depth of Sf Near Stake cms	Remarks
01	98	Sf	15	
02	109	Sf	9	
03	117	Sf	15	
04	105	Sf	4	
05	102	Sp		
06	121	Sf	11	
402	95	Sf (60%) and Sp (40%)		
403	101	Sf (40%) and Sp (60%)		
404	96	Sf (20%) and Sp (80%)		
405	90	Sf (10%) and Sp (90%)		
406	91	Sf (30%) and Sp (70%)		
407	78	Sf (10%) and Sp (90%)		
408	88	Sf (20%) and Sp (80%)		
409	80?	Sp (100%)		Mistake for 90?
410	86	Sf (50%) and Sp (50%)		

Remainder of stakes could not be reached because of blowing snow.

Original data in Robertson's notebooks.

19-20 May

Stake	Reading	% of Surrounding Area Covered by:		
		Old Sf	New Sf	Sf with Crust
01	115	90	10	
02	115	100		
03	134	10	90	
04	108	100		
05	103	15	85	
06	128	5	95	
402	96	100		
403	101	95	5	
404	96	90	10	
405	89	100		
406	91	90	10	
407	81	70	30	
408	85	45	55	
409	90	15		85
410	86	85		15
411	76	5		95
412	80	40		60
413	80	95		5
414	101	35		65
415	109	95		5
F2	117	50		50
416	108	15		85
417	107	50		50
418	105			100
419	100			100
420	101	15		85
421	100	75		25
422	100	20		80
423	106	50		50
BF1	90	85		15
424	86	80		20
426	75	40		60
425	77			100
427	69	90		10
428	84	60		40
429	88	90		10

26 May

Stake	Reading	New Sp	Old Sp	Mixed Old and New Sp	Old Sfr	Remarks
		% of Surrounding Area Covered by:				
01	104					9 cms new Sp
02	115					Trace new Sp
03	133					Trace new Sp
04	109					Trace new Sp
05	99					5 cms new Sp
06	130					6 cms new Sp
402	97	10	90			
403	100	10	90			
404	97			60	40	
405	91			30	70	
406	91			30	70	
407	80			60	40	
408	85			80	20	
409	90			90	10	
410	86			50	50	
411	77			85	15	
412	81			60	40	
413	80			50	50	
414	102			50	50	
415	109			60	40	
F2	117			50	50	
416	109			70	30	
BF1	80	50	50			
417	104			50?	?	
BF2	125	15?	85?			
418	102	30	70			
419	99	50	50			
420	100	10	10		80?	
421	100	20	80			
422	100			50	50	
423	99			50	50	
424	86		50		50	
426	77		50		50	
425	66		60		40	
427	70		50		50	
428	85		40?		50?	
429	88		85		15	

Original data in Robertson's notebooks.

2 June

Stake	Reading	% of Surrounding Area Covered by: Sp	Old Sfr	Remarks
01	105			Old Sp at stake
02	116	70	30	
03	133	100		
04	106	70	30	
05	100			Sp at stake
06	121			Sp at stake
402	98	20	80	
403	99	50	50	
404	96	85	15	
405	91	40	60	
406	91	60	40	
407	79	70	30	
408	86	85	15	
409	90	60	40	
410	86	50	50	
411	76	95	5	
412	80	75	25	
413	80	50	50	
414	103	60	40	
415	109	30	70	
F2	116	50	50	
416	108	30	70	
BF1	90	40	60	
417	105	50	50	
BF2	135	60	40	
418	100	70	30	
419	100	80	20	
420	100	50	50	
421	100	90	10	
422	100	70	30	
423				
424	87	50	50	
426	77	60	40	
425	68	70	30	
427	66	40	60	
428	82	50	50	
429	87	50	50	

Hoar frost on S-1 weather screen.

Original data in Robertson's notebooks.

9 June

Stake	Reading	% of Surrounding Area Covered by: New Sp	Old Sp	Sf	Depth of Sf Near Stake cms
01	105	95	5		
02.	115	80	5	15	
03	131	50	50		
04	108	100			
05	108?	100			
06	121	100			
402	95			100	
403	99			100	1
404	91			100	2
405	89			100	1
406	89			100	1
407	76			100	1
408	82			100	3
409	86			100	1
410	86			100	1
411	74			100	1
412	80			100	1
413	74			100	2
414	100			100	2
415	108			100	1
416	106			100	1
417	101			100	1
BF2	90			100	1
Trail Stake Near BF2	123				
418	101			100	2
419	98			100	
420	99			100	
421	98			100	
422	99			100	
423	98			100	2-3
424	81			100	1
426	64?			100	1
425	75			100	2
427	65			100	2
428	79			100	1
429	83			100	1

Original data in Robertson's notebooks.

16 June

Stake	Reading	% of Surrounding Area Covered by: Old Sp	Old Sfr
00			
01	112	100	
02	118	50	50
03	131	100	
04	109?	70	30
05	100	100	
06	110		
402	86	50	50
403	99	20	80
404	70	85	15
405	91	50	50
406	90	65	35
407	77	85	15
408	86	95	5
409	87	90	10
410	86	90	10
411	76	100	
412	81	85	15
413	78	60	40
414	103	60	40
415	108	50	50
416	109	60	40
417	104	70	30
BF2	125	100	
418	101	100	
419	91	100	
420	100	100	
421	100	100	
422	98	80	20
423	95	100	
424	84	50	50
426	77	50	50
425	67	70	30
427	70	50	50
428	81	50	50
429	87	40	60

Original data in Robertson's notebook.

24 June

Stake	Reading	Surface at Stake	% of Surrounding Area Covered by: Sp	Sp(icy)	I	Remarks
00	131	I				
01	112	I	30		70	
02	116	I	20		80	
03	105	Sp(f)	100			
04	110	I	70		30	
05	43?	Sp(d)	100			In drift area in lee of moraine
06	107	Sp(d)	100			
402	96	Sp(d-)	30		70	
403	100	I	5		95	
404	81	Sp	40		60	
405	91	I	15		85	
406	93	I	45		55	
407	76	Sp	45		55	
408	78	Sp	90		10	
409	87	Sp	60	40		
410	86	I	50		50	
411	76	Sp(icy)	15	85		
412	86	I	50		50	
413	77	Sp(3 cm on I)	55		45	
414	104	Sp(icy, on I)	40	10	50	
415	108	I	35	5	60	
416	109	I	95		5	
417	105	Sp(icy)	15	85		
BF1	85	Sp(icy)	10	60	30	
BF2	90	Sp(icy)	50		50	
418	103	Si	25	40	35	
419	92	Sp(icy)		100		
420	100	Sp(icy)		40	60	
421	100	Sp(icy)	10	50	40	
422	99	Sp(icy)		95	5	
423	95	Sp(icy)		95	5	
424	84	I		55	45	
426	80	Sp(icy)		70	30	
425	77	I	10	40	50	
427	80?	I	40		60	Misrecorded for 70?
428	82	Sp(icy)		60	40	
429	80	Sp(icy)		60	40	

Sp(icy) has an unspecified crust and is packed hard below.

The weather in the preceding week had been fair, except for strong winds on Thursday and Friday. Temperatures averaged -15° to -25° F.

Two approximate densities:
Ice near barrel above Stake 406 = 0.85
Snow from same place = 0.26

The flat areas below the Ramp were quite icy with Sd only in hollows. The Ramp itself had about 50% S. The lower cap was quite bare. Much of the remaining S had a thick ice crust which continued I areas as a thin layer of superimposed ice.

1 July

Stake	Reading	Surface at Stake	% of Surrounding Area Covered by: Sp	Sp(icy)	Sci	I	Remarks
00	131.5	I					
01	107	Sp	50			50	Sp at stake slightly icy. Partly in a drift. Surrounding Sp slightly icy
02	116.5	I	15			85	
03	107.5	Sp	15			85	Stake partly in an eroded drift
04	108	I	40	40		20	
05	61	Sp		100			Sp in surrounding area slightly icy
06	113.5	Sp		100			As for 05
402	97.5	I	10	10		80	Some of Sp less packed than that below
403	100	I	25		5?	60	Mistake in % total
404	91.5	Se	20		40	40	
405	91	I	20		5	75	
406	90.5	I	25		10	65	
407	80.5	Se on Si	20		35	45	
408	84	Se	30		40	30	
409	90	Sp on Sci	40		40	20	
410	86.5	I	40		30	30	
411	76.5	Se	10	60 Icy Sp and Sci		30	Se is icy
412	86.5	I	40		30	30	
413	79.5	I	50		10	40	
414	103.5	Sci	50		20	30	
415	108.5	I	40		20	40	
416	108.5	I	60		20	20	
BF1	85	Sp	70		30		
417	105.5	Sci	65		30	5	
BF2	90	Sp	60		40		
418	104	Sci	30		70		
419	92	Sp	60		40		
420	101	Sci	40		60		
421	100	Sci	50		50		Old summer surface? Many ice pellets
422	98.5	Sp	60		35	5	
423	96.5	Sp	75		25		
424	86	I	5		35	60	
426	72.5	Sp	25		45	30	
425	73	I	30		30	40	
427	69.5	I	40		20	40	
428	81	Sci	20		50	30	
429	75	Sp	40		10	50	

Sp(icy) is as for 24 June.

On the Ramp much bare ice; also wind eroded, mesa-like remnants of old ice crusted wind packed layers, standing about 8 cms above the ice surface. On the lower ice cap many partly eroded drifts standing up to 50 cms above the ice surface.

9 July

On 7 and 8 July the new snowfall left an average of 30 to 35 cms of low density snow. In the expectation that much of this light snow would blow away in the first strong wind, measurements on 9 July were restricted to a few soundings of the new snow thickness.

Stake	Thickness Near Stake	Remarks
00	30 cms	
02	37	
03	33	
05	30 - 40	
06	42	
403	31	
406	31	Some areas have 5 cms lightly packed
408	29	On 19 cms lightly packed: total 48 cms
410	31	
412	25	On 12 cms lightly packed: total 37
414	28	
416	22	Some areas have 10 - 12 cms lightly packed at bottom: total 33
BF1	20	Stake reading shows 18 cms accumulation
BF2	19	Stake reading shows 38 cms accumulation

The difference between the stake readings and the surroundings nearby at BF1 and BF2 is probably caused by a lightly packed snow layer under the unpacked layer.

Stake	Reading	Surface at Stake	% of Surrounding Area Covered by: Sf	Sp	Scr	I	Remarks
00	131.5	I	60			40	
01	69	Sf	98			2	I on ridge at 01
02	103	Sf	80	18		2	9 cm fresh on 24 cm packed. Locally elongated drifts with troughs eroded down to I. Sf is beginning to erode
03	89	Sp	80	15	5(Sci)		Sp at stake only lightly packed. Sp in surrounding area shows erosion forms. Areas of I and Sci on lower Grinnel and ridge up to Moraine
04	107.5	I	30	35	20(Sci)	15	
05	65	Sci	10	45	40	5	
06	113	Sp	10	50	40		
402	82	Sp	10	40	5	45	Drift forms in Sp at stake
403	95	Sp	20	60		20	All Sf and Sp slightly eroded
404	86.5	Sp	10	80		10	Sp in surrounding area lightly eroded
405	85	Sp		80	5	15	Sp as for 404. Lower cap has drifts up to 30 cm high
406	65	Sp		90		10	Sp has form of eroded drifts
407	66	Sp	10	80		10	Sp as for 406. Very white ice grades to snow with an icy crust 4 mm thick. Beneath is hoar layer 0 - 3 cms thick
408	76	Sp	5	90		5	Very white ice as for 407
409	78	Sp	5	90		5	
410	73	Sp	5	90		5	Sp has erosion forms
411	65.5	Sp	5	93		2	Sp as for 410
412	69	Sf	20	78		2	
413	61	Sp	10	85		5	Stake in slight drift from old stake
414	101	Sp	30	65		5	
415	105.5	Sf	20	70	5	5	5 cms of Sf. 15 ft. south of stake young (very smooth white) crusted snow area (crust 1 - 2 mm thick) grades into I surface
F2	97	Sf	30	68		2	
416	79	Sp	30	70			
BF1	69	Sp	30	70			
417	87	Sf	40	60			2 cms Sf on Sp
BF2	84	Sf	60	40			
Trail Stake Near BF2	77						4 cms lightly packed S at stake

Stake	Reading	Surface at Stake	% of Surrounding Area Covered by: Sf	Sp	Scr	I	Remarks
418	84.5	Sp	70	30			Lightly packed at stake
419	86	Sf	55	45			Occasional I patches with 5 cms I above hoar. 5 cms Sf at stake
420	92	Sf	60	37	2	1	I as for 419. 7 cms Sf at stake
421	89	Sp	40	60			
422	90	Sf	60	37		3	
423	90	Sf	50	48		2	1 cm Sf on Sp at stake
424	73	Sp	30	60		10	
426	57	Sp	20	70		10	
425	70	Sf	20	70		10	
427	54	Sf	20	65		15	Sf packing
428	35	Sp	20	65		15	Drifts of Sp
429	68	Sp	15	70		15	

The ridge mentioned in 03 is that of the perennial drift which runs down the Ramp in the lee of the lower moraine. This lower moraine is the one south of the prominent cone and was the site of point 5 on the subtense survey and of the northern moraine base in the horizontal movement survey.

At 04 the snow cover seemed to be thinning, probably by sublimation, until its original thin crust rested on the ice below and was bonded on as a thin layer of superimposed ice.

East of Flag 2 barrel a small excavation showed 2 - 3 cms ice with vapor figures (See section on Bubbles), probably an autumn phenomenon, on 3 cms of hoar and snow, all on ice.

21 July

100% Sf over the whole area

Stake	Reading	Depth of Sf cms	Remarks
00	125	8	
01	23	8	Meter stick pushed 68 cm into snow (i.e. 8 cm is only the recent accumulation)
02	80	8	
03	91	8	
04	100	8	
05	67	8	
06	97	8	
402	91	8	
403	87	6	
404	66	7	
405	66	6	
406	60	6	
408	66	5	
409	72	5	
410	69.5	5	
411	53.5	5	
412	57	5	
413	52	4	
414	93	4	
415	92	4	
F2	97	4	
416	75	4	
BF1	69.5	4	
417	80.5	4	
BF2	71.5	4	
Trail Stake Near BF2	70		
418	82	4	
419	75	4	
420	82	4	
421	81	4	
424	63	5	Stick pushed in 60.5 cms
426	43	5	Stick pushed in 47.5 cms
425	65	5	Stick pushed in 70 cms
428	53	5	Stick pushed in 52 cms
429	58	4	Stick pushed in 52 cms

19 July: Strong wind erosion with little new deposition on Ramp; on the cap little bare ice, but fairly smooth, lightly eroded snow, with hoar on the shelter and its cables at S-1.

21 July: Stakes and barrels coated with ice (3 - 4 mm thick) under rime, on the windward side. Rime formed on the vehicle during the measurement period.

22 July: Disappearance of Sf.

Stake	Reading	Surface at Stake	% of Surrounding Area Covered by: Sd	Sp	Scr	I	Remarks
00	130.5	Sp			20	80	2 cms of lightly eroded Sp
01	27(93)	Sp		50	50		Lightly eroded
02	85.5			40	60		
03	95	Scr		60	40		
04	95.5	Sp	20	30	50		
05	72.5	Scr	30	20	50		
06	98	Sp	30	20	50		Only lightly packed
402	91	Sp	40	20	40		Only lightly packed
403	87(98)	Sd	40	20	40		
404	65	Sd	60		40		
405	67	Sd	60		40		
406	60	Sd	85		15		
407	58	Sd	90		10		
408	62	Sd	80	10	10		
409	65	Sd	80	10	10		
410	61	Sd	80	10	10		
411	49	Sd	90	10			
412	49	Sd	100				
413	47	Sd	100				
414	90.5	Sd	100				
415	91	Sd	100				
F2	92	Sd	100				
416	71	Sd	100				
BF1	69	Sd	100				
417	78	Sd	100				
BF2	73(63)	Sd	100				
418	76.5	Sd	100				
419	73	Sd	95	5			
420	85	Sp	90	10			
421	84	Sp	90	10			
422	77	Sd	90	10			
423	71	Sd	95	5			
424	59(58)	Sd	95	5			
426	43(46)	Sd	95	5			
425	60(63)	Sd	90	10			
427	52(51)	Sd	95	5			
428	51(47)	Sd	90	10			
429	53(56)	Sd	90	10			

For meaning of figures in brackets see introduction to this section.

In general Scr is the lowest stratum of snow and comprises a slight unspecified crust above less than 2 cms of soft snow all above hard snow.

Sd and Sp occur in different places above Scr and grade locally into Sb.

The observations were made at night and percentages, therefore, are not precise.

There was some I on the ridges of the perennial drifts near the coast. There was more drifting on the south end of the profiles.

4 August

Stake	Reading	Surface at Stake	% of Surrounding Area Covered by: Sd	Sp	Sci	I	Remarks
00	129.5	Sci		30	30	40	
01	32.5(99)	Sp		100			Sp has icy crust and erosion features
02	87.5	Sp		100			Sp has icy crust
03	107.5	Sp		100			Sp has icy crust
04	106	Sp		98		2	
05	73.5	Sp		100			Sp has icy crust
06	87	Sp		100			Some Sp has icy crust
402	98	Sci		50	50		
403	84(95.5)	Sp		60		40	
404	69	Sp		100			
405	73	Sp		100			
406	65	Sp		100			
407	64	Sp		100			Some I between 406 and 407
408	67.5	Sp		100			
409	72	Sp		100			Some I below here
410	67			100			
411	57.5	Sp		90	10		
412	57	Sp		95	5		Sp has erosion features
413	52.5	Sp		100			Sp has crust
414	96	Sp	5	95			
415	66?	Sp	5	85	10		96? Sp has cru[illegible]
F2	100	Sp	5	85	10		
416	76.5	Sp	5	95			
BF1	73	Sp	5	95			
417	79.5	Sp		100			Sp has crust
BF2	74.5(73.5)	Sp		100			Sp has crust
418	76	Sp		100			Sp has icy crust
419	78.5	Sp		100			Sp has crust
420	79	Sp		100			Sp has crust
421	81	Sp		100			Sp has crust
422	71	Sp		100			Sp has crust
423	89	Sp		100			Sp has crust
424	62.3(63)			100			Sp has hard crust which collapses above softer stratum
426	45.5(51)	Sp		100			Sp at stake has crust
425	68.5(67.5)	Sp	5	95			Sp as for 424
427	53(54)	Sp		100			Sp as for 424
428	57.5(56.5)	Sp		100			Sp at stake has crust
429	60.5(61)	Sp		100			Sp at stake has crust

Patches of I as high as F2.

I surfaces above mid-Ramp have a hoar frost cover.

11 August

Stake	Reading	Surface at Stake	% of Surrounding Area Covered by: I	Sp	Scr	Remarks
00	129	Sci	50	50 Sp and Sci		
01	32.5(99.5)	Sp		100		
02	87	Sp		100		
03	107.5	Sp		100 Sp and Scr		
04	106.5	Sp on I	15	85 Sp and Scr		
05	73.5	Sci		50?	50?	
06	82.5	Sp		80	20	
402	97.5	I	60	40 Sp and Scr		
403	84(96)	Sp	20	80 Sp and Scr		The boundary between mostly I and mostly S was just below 403
404	69	Sp		100 Sp and Scr		0.5 to 2 cm Sf over all
405	73	Sp	5	95 Sp and Scr		0.25 cm Sf
406	65	Sp	5	95 Sp and Scr		Mostly Sp
407	64.5	Sp		100 Sp and Scr		Mostly Sp
408	68	Sp		100 Sp and Scr		1% I between 407 and 408 and again beyond 408
409	71.5	Sp		100 Sp and Scr		
410	67	Sp		100 Sp and Scr		Near S-1 an old I drift exposed
411	52.5	Sp	<1	99 Sp and Scr		
412	57	Sp		100 Sp and Scr		Crust collapses
413	52	Sp	<1	99 Sp and Scr		
414	94	Sp	<1	99 Sp and Scr		
415	95	Sp	<2	98 Sp and Scr		Between 414 and 415 is 3 - 4% I
F2	100	Sp		100 Sp and Scr		
416	77	Sp		100 Sp and Scr		
BF1	73	Sp		100 Sp and Scr		
417	79	Sp		100 Sp and Scr		
BF2	74(73)	Sp		100 Sp and Scr		
418	75	Sp		100 Sp and Scr		
419	78	Sp		100 Sp and Scr		
420	80	Sp		100 Sp and Scr		
421	81	Sp		100 Sp and Scr		Sp at stake quite hard
422	70	Sp		100 Sp and Scr		Almost all Scr. Sp at stake very hard
423	77	Sp		100 Sp and Scr		
424	62.5(63)	Sp		100 Sp and Scr		Crust collapses
426	44.5(51)	Sp		100 Sp and Scr		Crust collapses
425	65(67)	Sp	1	99 Sp and Scr		Crust collapses
427	53(54)	Sp		100 Sp anc Scr		Crust collapses
428	57(55.5)	Sp		100 Sp and Scr		Crust collapses
429	59(62)	Sp		100 Sp and Scr		Crust collapses

All the Ramp has a thin cover of powder snow.

Most of the snow referred to in the percentage study is probably wind packed snow with a hard layer at the top which is inadequately supported and collapses under weight.

19 August

Sf at all stakes

Stake	Reading	Average Depth of Sf cms	Remarks
00	117	11	Uneven cover with 5% of I in local area, and more I visible throug[h] only 3 cms of Sf
01	30(95)	8	
02	75	5	Level surface hides irregularitie[s] in surface below
03	97.5	12	
04	103	5	
05	70	5	
06	83	4	
402	92	7	
403	78(90)	5	
404	62.5	7	
405	66.5	9	
406	55	8	
407	56	9	
408	59	10	
409	51.5	8	
410	57.5		
411	42	15	
412	29	21	
413	47.5	11	
414	85	13	
415	85	12	
F2	88.5	7	
416	67	10	416 to 420 Sb to Sd with a slight thin crust
BF1	67.5	8	
417	66	15	
BF2	64.5(64.5)		
418	67	8	
419	66	10	
420	65	14	
421	70	10	
422	66	6	
423	70	9	
424	50.5(51.5)	12	
426	31(37.5)	16	
425	47.5(51)	12	
427	43(42.5)		
428	40.5(40.5)	17	
429	51.5(54)	12	

25 August

Stake	Reading	Surface at Stake	% of Surrounding Area Covered by: Sf	Sp	Scr	I	Remarks
00	124	Sd	85			15	
01	32(100)	Sd	100				
02	76.5	Sci	40		60		
03	101.5	Sd	30	30	40		
04	107	Sci	40	10	25	25	
05	73	Sci	30	30	40		Crust very icy
06	84	Sd	40	40	20		
402	97	I	10	15	30	45	
403	82(93)	Sd	60	5	30	5	
404	66	Sd	90	10			
405	68	Sd	90	10			
406	60	Sd	90	10			
407	61	Sd	90	10			
408	64	Sd	90	10			
409	58	Sd	90	10			
410	62.5	Sd	90	10			
411	50	Sd	85	15			
412	38	Sd	85	15			
413	47	Sp	85	15			Sp from here to 421 only lightly packed
414	91	Sp	80	20			
415	90	Sp	75	25			
F2	97	Sp	75	25			Wind packing and wind crusts become more marked higher on the cap
416	70	Sp	70	30			
BF1	67	Sp	70	30			
417	72	Sp	70	30			
BF2	67(68.5)	Sp	70	30			
418	72	Sp	60	40			
419	72	Sp	60	40			
420	70	Sp	60	40			
421	76	Sp	50	50			
422	71	Sci	45	45	10(Sci)		
423	73	Sp	45	50	5(Sci)		
424	57(55)	Sd	85	15			
426	37(43)	Sd	90	10			
425	54.5(55.5)	Sd	90	10			
427	48(48)	Sd	90	10			
428	48.5(47.5)	Sd	85	15			
429	55(59)	Sd	85	15			

27 August: Hoar frost on the S-1 shelter.

2 September

Stake	Reading	Surface at Stake	% of Surrounding Area Covered by: Sf	Sp	Scr	I	Remarks
00	114	Sf	90			10	
01	30(97)	Sf	100				Thin Sf on I
02	75	Sf	100				
03	91.5	Sf	99				1% is top of old Sd
04	105.5	Sf	100				Sf 1/2 cm at stake and thin generally
05	73.5	Sf	100				Thin Sf on Sci
06	27?	Sf	100				Reading appears doubtful
402	96.5	Sf	100				50% is I with thin Sf
403	84(94.5)	Sf	100				
404	63	Sf	100				
405	67	Sf	100				6 cm of Sf
406	64.5	Sf	100				Some Sf is thin on Scr
407	65	Sf	100				
408	58	Sf	100				
409	64	Sf	100				
410	66	Sf	100				Thin Sf on old Sd
411	55	Sf	100				
412	55	Sf	100				
413	51	Sf	100	Sf and Sp			
414	90	Sf	100	Sf and Sp			I patch between 414 and 415
415	95	Sf	50	45		5	
F2	86	Sf	90	10			
416	72	Sf	95	5			
BF1	73	Sp	80	20			
417	68	Sf	90	10			Sf is slightly wind worked
BF2	73(73.5)	Sf	10	90			
418	75	Sp	30	40	30		
419	75.5	Sp+	25	~50	~25		
420	76	Sp	25	~50	~25		Some I patches below profil
421	79.5	Scr	30	~40	~30		
422	71	Sci	20	~60	~20		
424	61(61)	Sf	100				Sf covers the 11 August collapsing layer which locally has icy crust
426	45(51)	Sf	100				
425	43(44)	Sf	100				Fairly heavy drifts
427	52(54)	Sf	100				
428	57(56.5)	Sf	100				
429	59(63)	Sf	100				

Over most of the cap old Sd topography shows beneath the Sf.

8 September

Stake	Reading	Predominant Surface and % of Surrounding Area Covered by it		Remarks
00	114.5	Sp	80	Patches I
01	(99)	Sp	100	
02	71	Sf	90	
03	82.5	Sp	100	Smooth
04	105	Sp	90	Thin crust. Patch of I
05	73.5	Sp	90	Smooth
06	87	Sp	100	Crust
402	96.5	I	95	5% Sp
403	85(95.5)	Sp	60	Large patches of I
404	69	Sp	80	
405	73.5	Sp	90	Patches of I
406	65	Sp	95	Small patch I
407	66	Sp	100	
408	50	Sp	95	Small patch I
409	61.5	Sp	95	
410	68	Sp	100	Stake in crusted drift
411	47	Sp		Crust. Some I
412	51	Sp	100	Crust. Ridges
413	52	Sp	100	Thin crust
414	89	Sp	100	I patch 1 - 200 feet across
415	96	Sp	100	Crust. I patch 25 feet across
F2	88.5	Sp	100	Hard crust. 25 cms S above I at barrel
416	67	Sp	100	Hard crust
BF1	72.5	Sp	100	Hard crust
417	79.5	Sp	100	Hard crust
BF2	73.5	Sp	100	Which stake not recorded
418	74?	Sp	100	Some doubt about stake
419	76	Sp	100	Hard crust
420	68.5	Sp	100	Hard Sp
421	75	Sp	100	Small drift at stake
422	71	Sp	100	Hard Sp
423	79	Sp	100	Hard Sp
424	48(54)	Sp	100	Crust
426	45.5(52)	Sp	100	Crust
425	50(51)	Sp	100	
427	47.5(50.5)	Sp	90	Small drift at stake
428	57(57)	Sp	100	
429	49(56)	Sp	100	Crust

Original data in file.

15 September

Stake	Reading	Predominant Surface and % of Surrounding Area Covered by it		Remarks
00	115	Sf	100	
01	(97.5)	Sf	90	10% Sb
02	76.5	Sf	70	30% Sp
03	57	Sf	60	40% Sp
04	105	Sp	75	I patches and small drifts
05	73.5	Sp	60	Crusted drifts
06	87	Sp	75	Drifts and rippled surface
402	94	Sp	60	35% I, 5% Scr
403	85.5(95)	Sp	80	10% I, 10% Scr
404	63.5	Sp	60	40% Scr
405	72	Sp	70	30% Scr. Small drifts
406	57.5	Sp	70	30% Scr
407	57	Sp	80	20% Scr
408	50	Sp	70	30% Scr. Small Drifts
409	60	Sb	65	35% Scr
410	65	Sb		Scr and Sp here
411	55	Sp	90	10% Scr
412	47.5	Sp	90	10% Scr
413	50	Sp	90	10% Scr
414	79.5	Sp	95	5% Sb
415	91	Scr	60	40% Sp
F2	84	Sp	100	Drifts
416	67	Sp	95	5% Scr
BF1	68	Sp	70	30% Sb
417	74.5	Sp	80	20% Sb
BF2	70(67.5)	Sp	80	20% Scr
418	72	Sp	90	10% Scr
419	73.5	Sp	90	10% Scr
420	68	Sp	100	Slight crust
421	76.5	Sp	80	20% Scr. Drifts
422	71	Sp	85	15% Scr. Drifts
423	78	Sp	80	20% Scr
424	63(61)	Sci	75	25% Sp
426	39.5(45.5)	Sp	50	50% Scr
425	50(53.5)	Sp	90	10% Scr
427	43(43)	Sp	50	50% Sb. 30 foot patch Scr
428	55.5(56)	Sp	95	5% Sb
429	49(52)	Sp	60	40% Scr

Original data in file.

22 September

Stake	Reading	% of Surrounding Area Covered by: Sp	Sb	I	Scr	Remarks
00	116	50	45	5		
01	(97)	40	60			Some crust
02	77	60	40			Some crust
03	64.5	50				Probably 50% Sb
04	100	40	40	20		
05	74	60			40	
06	72.5	80			20	
402	97.5		50	50		
403	84.5(95.5)	70	20		10	
404	53.5	50	40		10	
405	69.5	60			40	
406	59	40	40		20	
407	55.5	40	40		20	
408	58	40	50		10	
409	56	45	50		5	
410	60.5	60	30		10	
411	26.5?	30	70			Reading appears doubtful
412	45	30	60		10	
413	49	90			10	
414	80	70	20		10	
415	91.5	45	50		5	
F2	78	50	50			
416	64.5	50	40		10	
BF1	68.5	40	50		10	
417	63	50	40		10	
BF2	69	60	20		20	Which stake not recorded
418	69.5	60	20		20	
419	71	50	50			Some crusts
420	64	50	45		5	
421	76	60	30		10	
422	68.5	20	60		20	
423	74	40	30		30	
424	62(60)	60	20		20	
426	35.5(41)	40	30		30	
425	17?(51.5)	95			5	Reading appears doubtful
427	35.5(39.5)	20	10		70	
428	56.5(56.5)	40	40		20	
429	55.5(57.5)	45	45		10	

Original data in file.

29 September

Stake	Reading	% of Surrounding Area Covered by: Sp	Scr	I	Sci	Remarks
00	115.5	20	80			"Furrows." Small patches I
01	(99)	100				Well marked crust
02	77	100				Well marked crust
03	71	100				Crust
04	100.5	90		10		Crust
05	74	100				Glazed crust
06	78	70	30			Furrows
402	98	5		95		Furrows
403	85(95.5)	70		30		Crust
404	60	95				Glazed crust
405	68	70				Hard crust
406	66	60				Hard crust
407	66	50				Hard crust. Small drift
408	60	80				Crust. Furrows
409	61.5		100			Furrows
410	67.5	20	80			
411	53	30	70			
412	51		90		10	
413	52.5		80		20	
414	81		100			Furrows
415	92	40	60			Glazed crust
F2	84		100			Furrows
416	63		90		10	
BF1	72.5		90		10	
417	67	40	60			Furrows
BF2	74(73.5)	40	60			
418	69.5		80		20	Rough
419	76		90		10	Very rough
420	68.5		100			Very rough
421	78.5		90		10	Rough
422	71		100			Rough
423	76		100			Rough. Glazed crust
424	62.5(64)	20	80			
426	37.5(44.5)	40	60			
425	51.5(53)	80	20			
427	45.5(48)		100			Very furrowed
428	57.5(57.5)		100			Glazed crust. Furrowed
429	54.5(62)		95		5	Small drift at stakes

Original data in file.

The observer's "furrows" were probably incipient sastrugi.

Percentages not completed.

6 October

Stake	Reading	% of Surrounding Area Covered by: Sp	Scr	I	Sf	Remarks
00	111	75	15	10		
01	(95)	100				Crust
02	77	100				
03	69.5	100				
04	98.5	80			20	
05	74	90			10	Sf in drifts
06	78	85			15	
402	98			80	20	Sf in drifts
403	85(96)	75		25		
404	60	75			25	
405	67	80			20	
406	62	85			15	
407	62.5	60			40	Sf has drifts
408	55	75			25	Crust
409	61.5	85			15	Crust
410	63	80			20	
411	45	90			10	Drift near stake
412	46.5	85			15	Drift near stake
413	52	95			5	Crust
414	81	95			5	Crust
415	87.5	100				Drifts
F2	84.5	90			10	Drifts
416	62.5	85			15	Sf in large drifts
BF1	68	90			10	Sf in small drifts
417	67	90			10	Sf in small drifts
BF2	70.5(63)					
418	69	100				Drifts
419	71	75			25	Sf in drifts
420	60	75			25	Sf in large drifts
421	78.5	100				Drifts
422	69.5	95			5	Sf in drifts
423	76	95			5	Sf in drifts
424	63(62)	75			25	Crust. Small drift at stake
426	37(43)	70			30	Crust
425	51.5(54)	90			10	
427	41(43)	80			20	
428	57.5(56.5)	80			20	
429	54.5(59)	85			15	Small drifts. No notch on 59: read to top

Original data in file.

13 October

Stake	Reading	% of Surrounding Area Covered by: Sp	Sb	I	Scr	Remarks
00	113	50	50			I patch
01	(100)	70	30			
02	78	80	15	5		
03	58.5?	90	10			Should be 68.5?
04	98	60	40			
05	74	20			80	
06	79	20			80	
402	98	20		80		
403	85(96)	80		5	15	
404	49.5	30			70	
405	68	20			80	
406	66				100	
407	61		50		50	
408	49	40			60	
409	58	95		5		
410	67.5	25		5	70	
411	53.5	70	30			
412	45	100				Crust
413	52.5	100				Crust
414	83.5	90		10		Crust
415	92.5	100				Crust
F2	85	90		10		Crust
416	63.5	100				Crust
BF1	72.5	100				Crust
417	68			10	90	
BF2	74.5(74)	100				Drifts
418	70	100				Large drifts. Very rough
419	76.5	90		10		Large drifts
420	67.5	100				Large drifts
421	80	90		10		Large drifts. Crust
422	71.5	100				Large drifts. Crust
423	77	90		10		Large drifts. Crust
424	63(63)	100				Crust
426	38(45.5)	100				Crust. Small I patch
425	51.5(55)	100				Crust
427	44(47)	90		10		Crust
428	58(57.5)	90		10		Crust
429	56(60)	100				Crust. Drift at stake

Original data in file.

20 October

Stake	Reading	% of Surrounding Area Covered by: Sp	Scr	I	Sb	Remarks
00	101.5?	80	20			Should be 111.5?
01	93.5	95	5			Probably refers to new stake
02						
03	66.5	100				
04	100	100				Crust
05	74.5	60	40			
06	80		100			
402	98			90	10	
403	85(97)	95		5		
404	55	100				
405	69	10	90			
406	67	30	70			
407	66	20	80			
408	60.5		100			
409	59	25	75			
410	69	5	95			
411	54.5	10	90			
412	52	10	90			Drifts
413	53.5	5	95			
414	84	5	95			
415	93	5	95			
F2	86	5	95			
416	65	10	90			
BF1	69		100			
417	68.5		100			
BF2	75(74)		100			
418	70				100	Sb fresh
419	77				100	Sb fresh
420	67				100	Sb fresh. Crust
421	80.5				100	Sb fresh
422	72.5				100	Sb fresh
423	77.5				100	Sb fresh over crust
424	64(64)	15	85			
426	40(46.5)	5	95			
425	52(54)	5	95			
427	46(48.5)	20	80			
428	59(58)	25	75			
429	54(59)	15	85			

Fresh snow fell in camp one or two days before this.

Original data in file.

27 October

Stake	Reading	% of Surrounding Area Covered by: Scr	Sp	I	Remarks
00	110	70	30		
01	(72)?	100			Change in this figure appears real
02	98?	95		5	Misreading?
03	72	100			
04	100	100			
05	75	90	10		
06	80	95	5		
402	99	30		70	
403	86(95)	75		25	
404	62	70	30		
405	68.5	100			
406	67	100			
407	66.5	95	5		
408	61	100			
409	58	100			
410	60.5	20	80		
411	54	95	5		
412	52.5	85	15		
413	54	85	15		
414	84.5	80	20		
415	93	95	5		
F2	86	100			
416	65	100			
BF1	69	100			
417	69.5	95	5		
BF2	73(74.5)	70	30		
418	70.5	100			
419	77.5	100			
420	69	100			
421	81	100			
422	72.5	100			
423	77.5	100			
424	64(65)	100			
426	40.5(47)	90	10		
425	52.5(55)	100			
427	46.5(49)	95	5		
428	59(58)	100			
429	54.5(59)	100			

Original data in file.

3 November

Stake	Reading	% of Surrounding Area Covered by: Scr	Sp	Sf	I	Sb	Remarks
00	114	60	20	20			
01	73	70	30				**Probably refers to new stake**
02	80.5	30	50	20			
03	69	40		60			
04	99.5	40	40	15	5		
05	76	80		20			
06	81	80		20			
402	100	20			80		
403	85(95.5)		40	40	20		
404	61		30	70			
405	66.5			70		30	Thin S over I
406	66.5		20	20		60	
407	66		20	80			
408	61		50	50			
409	56.5		40	60			
410	65		10	90			
411	54		15	85			
412	47.5		20	80			
413	50			90		10	
414	82.5			80		20	
415	92			90		10	
F2	83.5			90		10	
416	62.5			95		5	
BF1	67.5			90		10	
417	68			90		10	
BF2	71.5(69)			90		10	
418	65.5			90		10	
419	70			80		20	
420	65.5			85		15	
421	78		15	85			
422	67		10	90			
423	74		10	90			
424	62.5(61)		15	80	5		
426	42(47.5)		30	70			
425	52(56)		10	90			
427	45(47)		25	75			
428	58.5(57)		20	80			
429	54(60)	25		75			

Original data in file.

10 November

Stake	Reading	% of Surrounding Area Covered by: Scr	Sp	I	Sb	Remarks
00	104	50	40	10		
01	71.5	60	40			**Probably refers to new stake**
02	82	100				
03	69	100				
04	100	95		5		Very rough
05	76	70	30			Some I
06	81.5	100				
402	94.5		40	60		
403	83.5(96)	80		10	10	
404	56	90	10			
405	68.5	80	20			
406	68.5	100				
407	61.5	50	30		20	Drift at stake
408	61	90	10			
409	58	80	20			
410	60.5	20	40		40	
411	56	80	20			
412	37	40	30		30	
413	39.5	80	20			
414	83	85	15			I patches between 414 and 415
415	91.5	90	10			
F2	85.5	90	10			
416	65.5	60	20		20	
BF1	68.5	100				
417	71	50	50			
BF2	69(70.5)		20		80	
418	66.5		20		80	
419	72	60	20		20	
420	63	50	30		20	
421	75.5		50		50	
422	73		50		50	
423	73	10	60		30	Small drift at stake
424	65.5(60.5)	80	20			
426	40.5(47)	60	20		20	
425	53(56.5)	90	10			
427	31(37)	75	20		5	
428	59.5(58)	60	20		20	
429	54(60)	80	20			Drift at stake

Original data in file.

17 November

Stake	Reading	% of Surrounding Area Covered by: Sb	Sp	Scr	I	Remarks
00	104.5		95			Mistake in percentage
01	73.5		80	20		Sun reflecting crust. (Old stake?)
02	82.5		85	15		Sun reflecting crust
03	73		100			
04	100		100			
05	71.5	15	85			
06	81.5	10	90			
402	95.5		35		65	
403	83(97)		100			
404	56.5		100			
405	68		100			
406	68.5		100			
407	62.5		100			
408	55		100			
409	58	5	95			
410	61.5	10	90			
411	78		100			
412	39		100			Sp has crust
413	40		80	20		Sun reflecting crust
414	83		90	10		Sun reflecting crust
415	91.5	20	80			
F2	84	10	90			
416	65.5	10	90			
BF1	78.5	5	95			
417	66	5	95			
BF2	100.5		100			Probably misread to top instead of to notch
418	66	50	50			
419	65	50	50			
420	63.5	5	95			
421	75.5	50	50			
422	73.5		100			
423	73	20	80			
424	65.5(64.5)	5	95			
426	40.5(47.5)	5	95			Sp has crust
425	53(51.5)	20	80			
427	32(38)	10	90			
428	29(26)	40	60			
429	54(60.5)		100			

Stake 01 reading probably refers to new stake.

24 November

Sf covers the whole area

Stake	Reading	Approximate Depth of Sf cms	Remarks
00	104.5		
01	30(100)	4	
02	81	3.5	Sf sticky on old surface of smooth hard snow without crust
03	66.5	4.5	
04	98		
05	71	2 -3	
06	80	2 -3	Below the moraine the surface snow is slightly moist; that 6" down not so. And, below the moraine many old drifts a few inches high buried under Sf
402	94.5	6 -7	On the ice cap old drifts up to 30 cms are partially or wholly buried by Sf
403	82(95)	3 -4	
404	54	7 -8	
405	66	8	
406	62	4 -5	
407	59	6 -7	
408	54.5	7 -8	
409	52.5	4 -5	
410	63	5 -6	Surface snow still slightly moist above here
411	51.5	6	20 cms sounded to hard surface
412	35	6	39 cms sounded to hard surface
413	37	8	40 cms sounded to hard surface
414	81	4	20 cms sounded to hard surface
415	88	8	18 cms sounded to hard surface. Beneath the Sf a weakly cemented stratum ~1 cm thick and crusted was noted to flex elastically.
F2	87	6	10 cms sounded to hard surface. Surface snow no longer moist.
416	59.5	5	45 cms sounded to hard surface. Stronger crust and more Sp under the Sf
BF1	57	5	30 cms sounded to hard surface
417	64	3	42 cms sounded to hard surface. Locally some Sp with a hard but breakable crust
BF2	64(65)	7	25 cms sounded to hard surface. Crust not so well developed
418	65	2	40 cms sounded to hard surface
419	62	2	32 cms sounded to hard surface
420	54	8	45 cms sounded to hard surface
421	74	6	21 cms sounded to hard surface
422	66	6	35 cms sounded to hard surface
423	61	5	40 cms sounded to hard surface
424	58(55)	4	22 cms sounded to hard surface
426	37(42)	6	42 cms sounded to hard surface
425	50(53)	3	29 cms sounded to hard surface
427	34(31)	3	33 cms sounded to hard surface
428	47(46)	4	33 cms sounded to hard surface
429	53(58)	2	20 cms sounded to hard surface

1 December

Stake	Reading	Surface at Stake	% of Surrounding Area Covered with Sb	Sp	Scr	I	Remarks
00	101	Sb	100				
01	99.5	Sb	100				Probably refers to new stake
02	77	Sb	100				
03	64.5	Sb	100				
04	96	Sb	90	10			
05	73.5	Sp	40	60			Sp is crusted
06	78	Sb	70	30			
402	88.5	Sb	70			30	
403	81(92)	Sb	80	20			
404	53.5	Sb	70	30			
405	62.5	Sb	70	30			
406	61	Sb	40	60			
407	57.5	Sb	50	50			Drifts
408	53	Sb	50	50			
409	50	Sb	70	30			
410	61	Sp	20	80			
411	51	Sp		90	10		
412	33	Sp		100			Small drifts at stake
413	36	Sp		90	10		Small drifts at stake
414	78.5	Sp		90	10		
415	85.5	Sp		90	10		Small drifts at stake
F2	80	Sp		90	10		
416	59	Sp		90	10		Small drifts at stake
BF1	57	Sp		100			
417	62.5	Sp		90	10		
BF2	64(62)	Sp		90	10		
418	63	Sp		90	10		
419	61	Sp		80	20		
420	56	Sp		100			Small drifts
421	73.5	Sp		90	10		
422	63	Sp		100			Small drifts
423	61	Sp		100			Small drifts
424	55.5(54)	Sp		95		5	
425	36(41.5)	Sp	30	70			
425	49.5(53)	Sp	40	60			
427	30.5(34)	Sp		100			
428	47(45)	Sp		100			
429	53(58.5)	Sp		95	5		

Original data in file.

8 December

Stake	Reading	Surface at Stake	% of Surrounding Area Covered by Sg	Sp	Sb	I	Remarks
00	107	Sg					
01	33(103)	Sg	100				Sg has crust
02	78.5	Sg					Sg has crust. Up to 0.5 cm of Sf
03	72	Sb on Sg	50	50			
04	101.5	Sg	80	20			Sg at stake has crust.
05	77	Sg	70	30			Sg at stake has crust. Some crust collapses
06	79	Sg	80	20			Sg at stake has crust above settled snow. Melt areas around moraine rocks
402	98.5	I	15	5		80	Large areas of I with a thin crust of new I (formed by melting of thin snow cover) up to 1 cm above the surface but sometimes in contact with the old I
403	87.5(98)	Sfr	70	15		15	Some local Sd
404	46?	Sg	80		20		Mistake for 56? Some collapsing crust
405	64	Sg	70		30		Some collapsing crust. Small patches of I between 405 and 406 at slope change
406	69.5	Sg(hard)	70		30		
407	55	Sg(fine)	70		30		I with crust below 407 barrel
408	58.5	Sp	70	Sg and Sp	30		Sp at stake metamorphosing as Sg
409	54	Sb	50	Sg and Sp	50		3 cms of Sb. I patch between 408 and 409
410	56	Sp	60	Sg and Sp	40		Sp at stake metamorphosing as Sg
424	62(60)	Sg	~60		~40		Sg at stake metamorphosing and crusted
426	33(41)	Sg	~60		~40		Sg at stake metamorphosing and crusted. Hard
425	54(56)	Sg					Sg at stake metamorphosing and crusted. Hard. Collapsing crust

On the Ramp a few patches of I, mostly covered by very thin Sg, which is sometimes melted completely.

On 9 December, a cloudy day, some areas have I's on the surface but slush beneath. Some areas are recent clear Im. Above Grinnel Nunatak some areas resemble slush flows.

10 December

Stake	Reading	Surface at Stake	% of Surrounding Area Covered by: Scr Sg Sp I	Remarks
411	59	Sg	100 Sg and Sb	S slightly moist and beginning to metamorphose
412	38	Sg	100 Sg and Sb	S slightly moist and beginning to metamorphose
413	46	Sg	100 Sg and Sb	Surrounding S slightly moist and beginning to metamorphose
414	85	Sg	100 Sg and Sb	Surrounding S slightly moist and beginning to metamorphose
415	95	Sg	97 Sg and Sb 3	Surrounding S slightly moist and beginning to metamorphose. Patch of blue ice near 415 seems to include 1 cm of new ice at top
F2	87	Sg	100 Sg and Sb	S beginning to metamorphose
416	67.5	Sg	100 Sg and Sg	S beginning to metamorphose. Sg crusted
BF1	61.5	Sg	100 Sg and Sb	Sg just beginning to metamorphose and has crust
417	69	Sg	100 Sg and Sb	Sg just beginning to metamorphose and has crust
BF2	69.5(71)			Surface is generally old blown snow now metamorphosing and with a crust
418	71.5			As for BF2 but snow more packed
419	66.5			As for BF2 but snow more packed
420	62	Sp	100 Scr, Sg and Sp	Sp at stake crusted
421	80	Sp	100 Scr, Sg and Sp	Sp at stake crusted
422	73	Sp	100 Scr, Sg and Sp	Sp at stake crusted
423	66	Sp	100 Scr, Sg and Sp	Sp at stake crusted
427	32(35)	Sp	100 Sg and Sb	All S is sticky
428	52.5(51)	Sp	100 Sg and Sb	All S is sticky
429	57(62)	Sp	100 Sg and Sb	All S is sticky

15 December

Stake	Reading	Remarks
00	110.5	Grain size at surface 1 - 2 mm
01	38(107)	
02	69	In tail of barchan like drift at 180° to wind
03	76.5	Slight crust probably due to night freezing
04	100.5	Slight crust probably due to night freezing
05	77	Slight crust probably due to night freezing
06	79	Slight crust probably due to night freezing
402	99.5	50% ice in surrounding area
A	103	A and B are superimposed ice stakes a few yards to the north of 402; A the northern and B the southern. They were inserted to read 100 between 5 and 13 September. This week they both have small pools at the stake top but are quite firm, having been inserted to 2 m. The surface hereabouts is smooth: a mixture of (1) Sg and (2) very thin Sg with ice pellets in contact with the Sg surface and the I below
B	101.5	
403	86(97)	Slight crust, 30% ice in surrounding area, mostly towards the moraine
404	55	Slight crust
405	64.5	Slight crust
406	68	Slight crust
407	55	Slight crust
408	55	
409	50	
410	51.5	Top 5 - 6 cm is moist. Below this loose powder with grain size less than 1 mm
411	54	
412	36	
413	44	
414	86	
415	92.5	
F2	85.5	Crust
416	64.5	
BF1	60.5	
417	69	
BF2	70	Which stake not recorded
418	71	
419	67	Crust
420	59.5	
421	77	
422	68.5	
423	66	
424	63(59)	
426	29(34)	
425	53(55)	
427	28.5(27)	
428	53(51.5)	
429	57(62.5)	

With the exceptions in "Remarks" the whole area is covered by Sg: metamorphosing and slightly moist.

Near the isolated moraine (See Northern Area Map) free water collects and flows in snow holes dug by foot. Melt separated ice crystals 3 - 6 mm in diameter can be kicked out below the snow. The saturation appears limited to areas with thin snow cover. Where supimposed ice occurs there is an abrupt change from a smooth old ice surface to a built up rough granular surface, and sometimes the new superimposed ice reaches the surface of the snow. In some areas with dirt, melting appears to have proceeded from below, leaving only a thin snow-ice crust as a cover to the old ice surface, and no trace of melt water. In the banded area near the isolated moraine pools of slush are held between the upstanding bands. Cryoconite holes up to 30 cms deep by 10 cms by 15 cms are filled with water.

22 December

Stake	Reading	Surface at Stake	% of Surrounding Area Covered by Sp	Sg	I	Remarks
00	112	Sg		80	20	I mostly refrozen slush
01	44(111)	Sg		100		Short stake 40° from vertical
02	73	Sg		100		Stake 15 - 20° from vertical
03	80	Sg		100		Stake 25° from vertical
04	105	Slush on I		100		Parts of Ramp look icy and have cover of refrozen slush
05	80	Sg	5	95		
06	81	Sg		100		
402	99	I		25	75	
403	88(99)	Sg		80	20	Sg particularly icy
404	58	Sg		97	3	Sg soft beneath. Small patches of blue slush
405	67	Sg		95	5	I in patches on slight ridge near 405
406	71	Sg		98	2	
407	58.5	Sg		97	3	
408	57.5	Sg		95	5	
409	53	Sg		100		Perhaps just less than 100; visibility poor
410	55	Sg		100		Sg crusted
411	56	Sg		95	5	Sg crusted. I may be refrozen slush
412	39.5	Sg		100		Sg crusted
413	47	Sg		100		
414	86	Sg		100		Perhaps just less than 100; visibility poor. Sg crusted. 3% I between 414 and 415
415	94.5	Sg		100		
F2	87	Sg		100		Sg crusted
416	65	Sg		100		
BF1	61	Sg		100		
417	70	Sg		100		Sg crusted
BF2	70(72)	Sg		100		
418	72.5	Sg		100		Sg has well developed crust
419	68	Sg		100		Sg crusted
420	62	Sg		100		
421	78.5	Sg		100		
422	70	Sg	5	95		Locally some crusted Sp
423	67	Sg		100		Sg crusted
424	66(59)	Sg		100		New stake 15° from vertical
426	31(38.5)	Sg		100		Sg crusted
425	55(56)	Sg		100		

Stake	Reading	Surface at Stake	% of Surrounding Area Covered by Sp	Sg	I	Remarks
427	31(30.5)	Sg		100		Sg particularly icy. Perhaps some Sp
428	54.5(54)	Sg		100		
429	58(64)	Sg		100		

All Sg appears to have been moist but refrozen.

At 402 most of the ice surface is very rough, but there are some generally very smooth drift forms composed of refrozen slush. The upwind side of some of these forms is rough, as if constructed or eroded by the wind or perhaps accreted by blown snow, whilst still thawed. The forms show signs of some free water flow over their surface, and are similar in appearance to those described for 8 December.

29 December

Stake	Reading	Surface at Stake	% of Surrounding Area Covered by Sg	I	Remarks
00	114	Sg	100		Sg refrozen after being moist
01	51(114)	Sg	100		Sg refrozen after being moist
02	78	Sg	100		Sg only partly refrozen
03	85	Sg	100		Sg only partly refrozen. Still moist
04	108	Sg	90	10	Sg moist and crusted
05	79	Sg	100		Sg moist and crusted
06	82	Sg	100		Sg moist and crusted
402	80?	Im/S	40	60	Stake melted out
M3	104				M3 is movement stake, inserted to 2 m on 3 May 1958
A	104				
B	106				
403	90(103)	Sg	50	50	
404	60	Sg	100		Sg moist
405	69.5	Sg	95	5	Sg moist
406	72	Sg	100		Sg moist. Maybe less than 100. I patches between 406 and 407
407	59	Sg	100		Sg hard
408	59	Sg	100		Sg hard
409	54	Sg	100		
410	55.5	Sg	100		
411	57	Sg	100		Sg hard
412	42	Sg	100		Sg crusted
413	48	Sg	100		Sg crusted
414	87	Sg	100		Sg crusted. I up to 5% between 414 and 415
415	96	Sg	98	2	Sg crusted and hard
F2	87	Sg	100		Sg crusted and hard
416	66	Sg	100		
BF1	62	Sg	100		
417	70	Sg	100		
BF2	71(72.5)	Sg	100		
418	73	Sg	100		
419	68.5	Sg	100		
420	63	Sg	100		
421	79	Sg	100		
422	70	Sg	100		
423	67	Sg	100		Sg crusted and only slightly metamorphosed
424	66(60)	Sg	100		
426	32(38)	Sg	100		Sg is hard
425	55(57)	Sg	100		Sg is hard
427	31(31)	Sg			Sg is hard

Stake	Reading	Surface at Stake	% of Surrounding Area Covered by Sg	I	Remarks
428	55(55)	Sg			
429	62(65)	Sg	100		Sg crusted and hard

Radiation hollows developing well on Ramp and below, particularly on old drift ridges.

Snow is ablating from below and leaving a thin film of icy snow at the surface.

At 402, particularly above the main shear, there has been abundant melt water. In places the flow has refrozen to solid ice; in others it has refrozen as ice on top of snow.

Between 402 and 403 the surface ice is extremely rough, probably the result of either uneven welding on of new snow or of earlier melting along crystal boundaries.

6 January 1959

Stake	Reading	Surface at Stake	% of Surrounding Area Covered by Sb	Sg	I	Remarks
00	117	Sg		100		Sg is moist
01	56(82?)	Sg		70		Sg is moist. 82 misread? 30% slush over I
02	80	Sg				Sg is moist
03	92	Sg		100		Sg is moist
04	92	Sb	5	50		Sb is moist. Mistake in percentage
05	81	Sb	80	20		Sb is moist
06	83.5	Sb				Sb is moist
M3	104	Sb and I	~50		~50	High areas are S and low ones I, as in some radiation hollows. Some of the I probably frozen slush
403	89(102.5)	Sb		80	20	Thin cover moist Sb
404	61	Sb	100 Sb and Sg			Sb at stake moist and crusted. 30% of Sf and Sb is very thin and overlies probably new superimposed ice
405	69	Sb	95 Sb and Sg		5	Sb at stake moist. 25% of Sf and Sb is very thin and overlies probably new superimposed ice
406	72	Sb	98 Sb and Sg		2	Sb at stake moist
407	60	Sb	96 Sb and Sg		4	Sb at stake moist
408	59.5	Sb	97 Sb and Sg		3	Sb at stake moist
409	54	Sb		99	1	Sb at stake moist
410	58	Sb		100		
411	59.5	Sf/Sb		100		Sf/Sb at stake moist
412	41	Sf/Sb	100			Sf/Sb at stake moist. Grades downslope into more metamorphosed Sb and Sg
413	47	Sb	100 Sb and Sg			
414	90	Sb	100 Sb and Sg			3% I between 414 and 415
415	97	Sb/Sg	99 Sb and Sg		1	
F2	89	Sb/Sg		100		Sb/Sg at stake moist
416	66	Sb/Sg	~40	~60		Sb/Sg at stake moist
BF1	60	Sb/Sg	100 Sb and Sg			Sb/Sg at stake moist
417	71	Sb/Sg	100 Sb and Sg			Sb/Sg at stake moist
BF2	72(73)	Sb/Sg	100 Sb and Sg			Sb/Sg at stake moist
418	73	Sg	100 Sb and Sg			Sg at stake is moist and crusted. Approximately 40% of the snow cover on the upper profile

Stake	Reading	Surface at Stake	% of Surrounding Area Covered by Sb	Sg	I	Remarks
						is of drifts elongated in the direction of the wind.
419	69	Sg	100 Sb and Sg			Sg at stake crusted and moist but only slightly metamorphosed
420	64	Sg	100 Sb and Sg			Sg at stake crusted and moist but only slightly metamorphosed
421	81	Sg	100 Sb and Sg			Sg at stake crusted and moist but only slightly metamorphosed
422	72	Sg	100 Sb and Sg			Sg at stake crusted and moist but only slightly metamorphosed
423	69	Sg	30	70		Sg at stake crusted and moist but only slightly metamorphosed
424	66(61)	Sb/Sg	100 Sb and Sg			Sb/Sg at stake crusted
426	34(41)	Sb/Sg	100 Sb and Sg			Sb/Sg at stake crusted
425	57(61)	Sb/Sg	100 Sb and Sg			Sb/Sg at stake crusted
427	34(34)	Sb/Sg	100 Sb and Sg			Sb/Sg at stake crusted
428	57(55)	Sb/Sg	100 Sb and Sg			Sb/Sg at stake crusted
429	59(62)	Sb/Sg	100 Sb and Sg			Sb/Sg at stake crusted. Moist

Sb in the above is slightly metamorphosed.

On the upper Ramp and the moraine snow is plastered onto the surface, in some places in drifts with the cross section of small escarpments, the scarp slopes facing upwind. The snow is new but already moist. On the upper profile ice pellets are visible near the snow surface.

13 January

Stake	Reading	Remarks
00	116	
01	61.5(115)	
02	80	
03	87.5	
04	105.5	
05	81	
06	88.5	
A	104	
B	100	
403	89.5	Old stake only
404	60.5	
405	76.5	
406	74	
407	60.5	
408	58	
409	53.5	
410	57	
411	54	
412	44	
413	43	
414	89.5	
415	91.5	
F2	84	
416	67	
BF1	61	
417	69	
BF2	106.5	Probably read to top instead of notch
418	70	
419	66	
420	58.5	
421	77	
422	71	
423	66.5	
424	67.5	Old stakes only from here
426	33.5	
425	55	
427	31	
428	57.5	
429	59?	Reading doubtful

Sf at all stakes.

Original data in Hollin's notebook.

20 January

Stake	Reading	Remarks
00	120	
01	70.5(119)	
02	85.5	
03	94	
04	110	
05	85	
06	92	
M3	106.5	Believed to be M3; data blurred
403	92(105)	
404	60.5	
405	73	
406	78	
407	62	
408	58	
409	53	
410	57.5	
411	55	
412	43.5	
413	42	
414	87	
415	91	
F2	83	
416	64	
BF1	59	
417	68.5	
BF2	70(70)	
418	69	
419	66	
420	56	
421	76.5	
422	69	
423	66	
424	67.5(61)	
426	33.5(37)	
425	54(56.5)	
427	32(33.5)	
428	57(57.5)	
429	58(61.5)	

All stakes have slightly moist fresh snow.

Near 04 the ice below Sf had melted at its boundaries to a depth of 35 cms and could easily be excavated. Free water ran into the hole so formed.

26 January

Stake	Reading	% of Surrounding Area Covered by Sg	I	Remarks
00	122	100-		
01	73.5	100		Which stake not recorded
02	88	100		
03	98	100		
04	112	98	2	
05	86.5	100		
06	95.5	100		
M3	107	90	10	Sg thin over I
403	93(107)	100		Sg thin over I
404	66.5	100		50% of Sg is thin over I
405	74.5	100		50% of Sg is thin over I
406	75.5	100		40% of Sg is thin over I
407	63.5	100		30% of Sg is thin over I
408	60.5	100		
409	55	100		
410	58.5	90	10	
411	56	98	2	
412	44	100		
413	44	100		
414	89.5	100		
415	93	100		5% of Sg is thin over I
F2	84	100		
416	67.5	100		
BF1	60	100		
417	69	100		
BF2	72(69)	100		
418	70.5	100		
419	67	100		
420	59	100		
421	78	100		
422	70.5	100		
423	67	100		
424	61(63.5)	100		
426	34.5(38.5)	100		
425	56.5(59)	100		
427	33(35)	100		
428	59(58)	100		
429	60(63.5)	100		

All stakes have Sg which appears to have been moist but is frozen at the time of observation.

2 February

Stake	Reading	Surface at Stake	% of Surrounding Area Covered by Sb	Sg/Sfr	I	Remarks
00	108	Sfr		95	5	
01	74.5	Sfr		100		Probably refers to old stake
02	88	Sfr		100		
03	98.5	Sfr		100		
04	114.5	Sfr		90	10	
05	88	Sfr		95	5	
06	96	Sfr		100		
402	109.5	Sfr	10	80	10	Formerly M3
403	94(106)	Sg		98	2	
404	65	Sg		95	5	Some mixed patches S and I
405	75	Sg		97	3	
406	73	Sb		97	3	
407	64	Sg		99	1	
408	60	Sg	3	96	1	
409	55	Sg	5	94	1	
410	60	Sg	5	95		
411	57	Sb/Sg	15	85		
412	45.2	Sb/Sg	15	85		
413	45	Sb/Sg	15	85		
414	89.5	Sb/Sg	15	85		
415	94	Sb/Sg	15	85		
F2	85.5	Sb/Sg	20	80		
416	58	Sb/Sg	20	80		
BF1	62	Sb/Sg	20	80		
417	70	Sb/Sg	20	80		
Bf2	72(70)	Sb/Sg	20	80		
418	71	Sb/Sg	20	80		
419	68	Sb/Sg	20	80		
420	60	Sb/Sg	20	80		
421	79	Sb/Sg	20	80		
422	71.5	Sb/Sg	20	80		
423	68	Sb/Sg	20	80		
424	62(65.5)	Sb/Sg	15	85		
426	35(40)	Sb/Sg	15	85		
425	57(60)	Sb/Sg	15	85		
427	23.5(25.5)	Sb/Sg	15	85		
428	59(59)	Sb/Sg	15	85		
429	60.5(64.5)	Sb/Sg	15	85		

5. The S-2 trail

These measurements on 1-1/2-inch diameter halfrounds continue directly from those of 1957. RF8 was broken early in the year and replaced by a split bamboo. Readings on it are not continuous from 1957.

	RF1	RF2	RF3	RF4	RF5	RF6	RF7	RF8	Remarks
10 Feb 58	147.5	137.5	144	143	151	141			Icy area to the seaward side of RF6.
18 March	149	138	133	144	152	138			Hard crusted drifts at RFs 1-4. Sastrugi at RF5.
3 Apr	145.5			143	151.5	144			On this journey much less wind noted at RF6.
7 Apr	134	138.5	131	143.5	151.5	139	132.5		
16 Apr							132.5		
17 Apr	146	136.5	131	142.5					Much new snow at RF2.
2 May						143	133		These measurements after the year's strongest wind. High and hard sastrugi lineated from the NE. Surface crusted at both flags.
7 May	130	126.5	126	134	131	139	132	124.5	Crusted surface at RF8, which is a new stake, not continuous from 1957.
5 June	131	124	125	143.5	137.5	137		121	
14 July				136	122.5	120	128	111	Mostly unconsolidated following heavy falls. Slightly eroded at RF4 and 5. Crusted surface at RF6.
22 July						116	102	103	After heavy falls, not yet windblown.
1 Aug								98	
4 Aug	116.5	112.5	107	107.5	109	120	106		After two weeks of fine weather with light winds. Some doubt about figures for RF2 and RF4.
3 Sept	117 Sci150 Sp50	104.5 Sci140 Sp60	97 Sci150 Sp50	108.5 Sci175 Sp25	110 Sci175 Sp25	111.5 Sci180 Sp20	99.5 Sci185 Sp10 Sf5	97.5 Sci195 Sf5	For meaning of abbreviations see Section VI-B-4. Some erosion at every flag. Tracks from 4 Aug. visible over 50% of route except Miles 35-45 where 25%.
12 Sept								95	Lightly eroded new snow at RF8.
16 Nov	118	94.5	98	103	100	111.5	97.5	86.5	See Section VI-A-3.

7 Jan 59	118	102	102	105	109.5	109	104.5	91.5	See Section VI-A-3.
17 Jan	119	102.5	103	105.5	110.5	110	101	89.5	Windpacked snow, most of surface with erosion-forms above RF3 and with crusts below RF4.
30 Jan		102	104	106	110.5	111	99	90	

6. S-2

These measurements on three Weather Bureau stakes continue directly from those of 1957. The average reading of the three stakes is given in inches. Note that on these stakes higher readings mean a higher snow surface. By now (1961) these stakes, some 50 meters to the SE of S-2, are probably affected by the general station drift, and new stakes are needed several hundred meters upwind. S-2 was occupied only intermittently in 1958, and the small amount of weather data available for use with these figures is held by the U. S. Weather Bureau at Asheville, North Carolina.

26 March	15	13 April	15
27 "	15	14 "	15
28 "	15	15 "	15
29 "	15	16 "	15
30 "	15	17 "	(Hoar on antennae)
31 "	15	7 May	21
1 April	14	15 "	22
3 "	15.5	17 "	15
4 "	14	19 "	22
5 "	14	4 Aug	29.5
6 "	14	3 Sept	33.3
7 "	15	4 "	33
8 "	15	16 Nov	33.3
10 "	16	8 Jan	32.7
11 "	15	30 "	32
12 "	15		

7. S-2 network

The network of 1-1/4-inch diameter bamboo stakes inserted for the Movement survey at S-2 was also used for occasional accumulation measurements. The readings continue directly from 1957, with the exception of those on stake A, which was disturbed and reset early in 1959. The position of the stakes is shown in Fig. 18. Movement survey data shows that the maximum slope in any part of the stake area was probably less than 40', and the measurements should therefore give a good average for the S-2 area.

Stake	20 May 58	27 May 58	1 June 58	10 Jan 59	15 Jan 59	17 Jan 59
A				157 (stake reset before this date)		
B		189		175		
C	209			171		
D		225.5		202		
E			198	171		
F	200			167		
G	222				194	
H	160					132
I	183					149
J		205				179
K		204				167
L		173				137

Figs. 23 and 24. Radiation hollows on Clark Island, looking SW. Photographs by J. Hollin

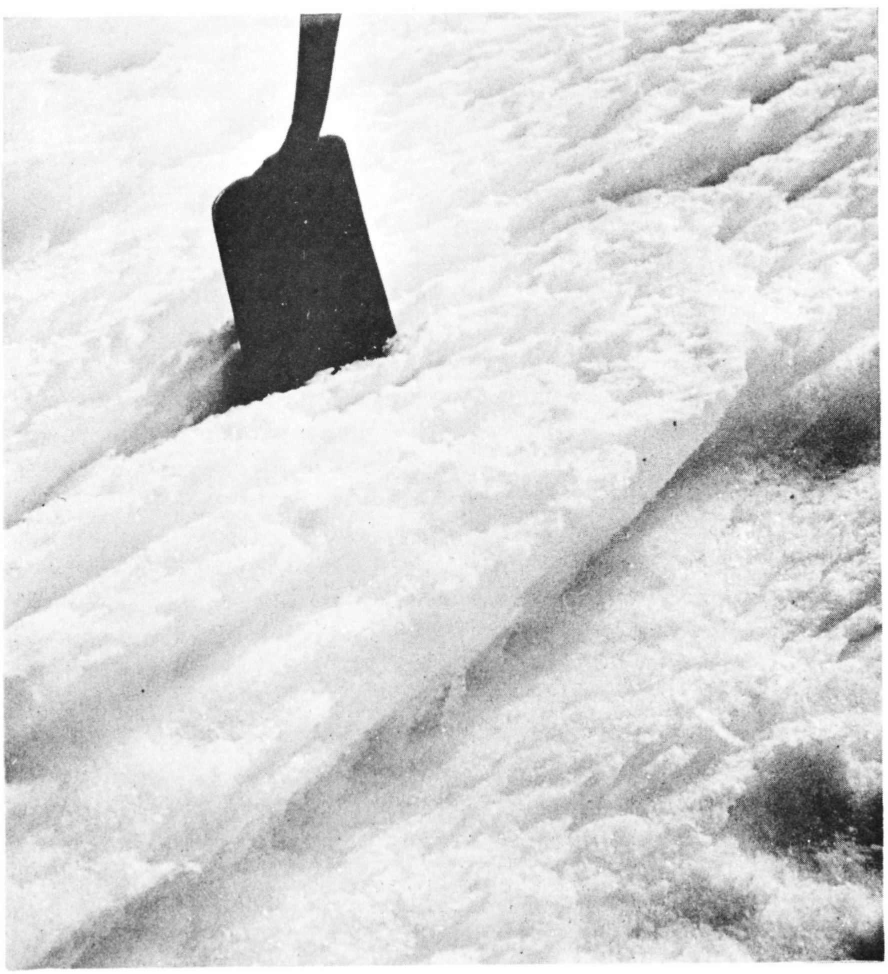


Fig. 25. Firn pinnacles on the west coast of Browning Island. Looking E to Point 254. Photograph by J. Hollin.

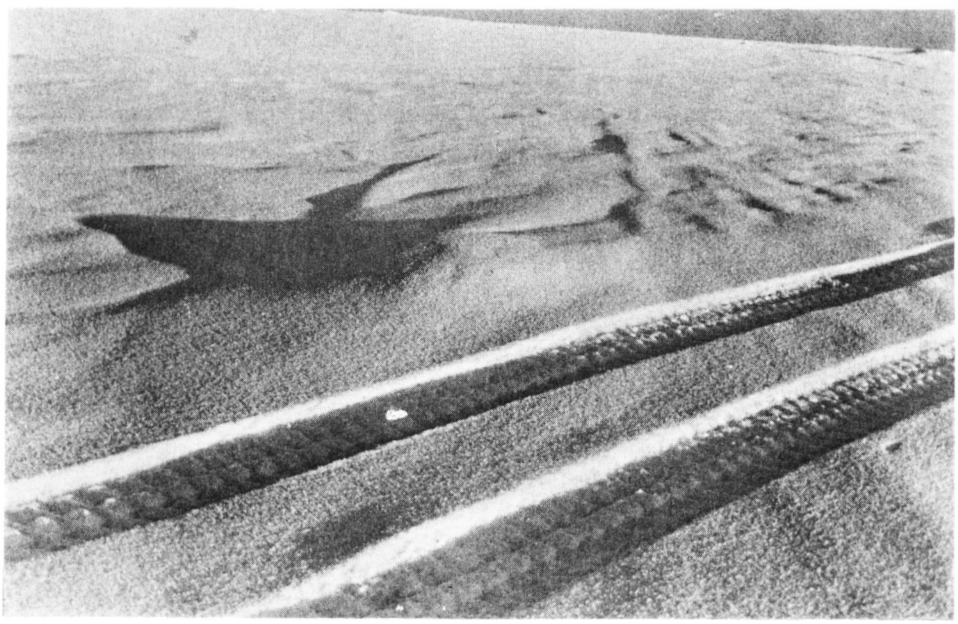


Fig. 26. Hoar-frost on new snow with ripples, on the lower ice-sheet. Photograph by J. Molholm

Fig. 27. Tiles. Wind from the left. Photograph by J. Molholm, taken on the Ellsworth Highland Traverse, 1960-61.

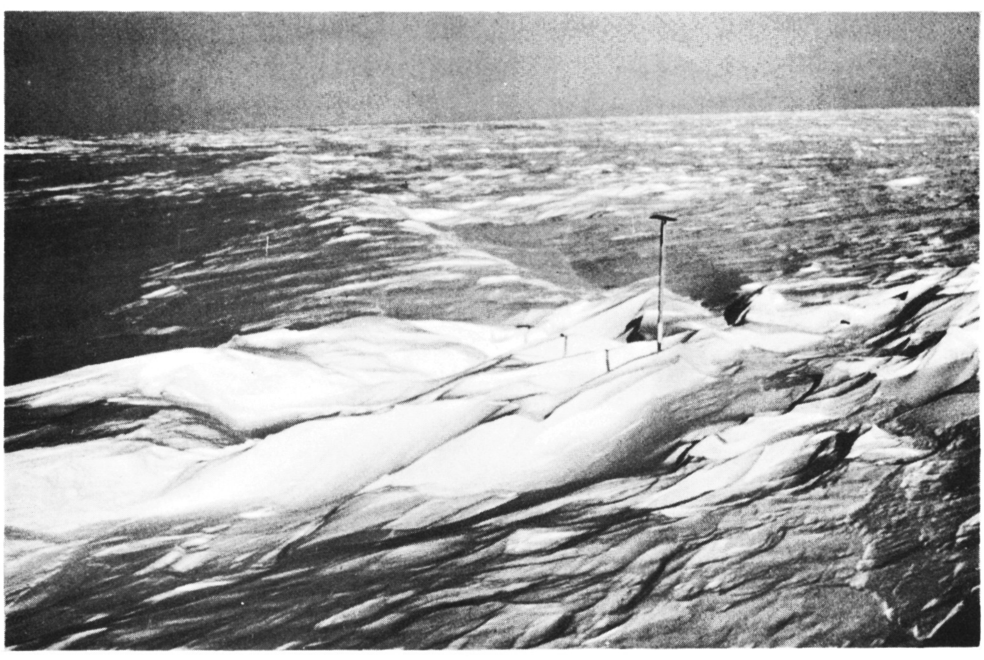


Fig. 28. Linear Dune in direction of photograph, cut into sastrugi by wind from right. Photograph by J. Hollin, taken on the Wilkes Station Traverse, 1958.

Fig. 29. Sastrugi at S-2, looking WNW. Wind from ESE. Photograph by J. Molholm.

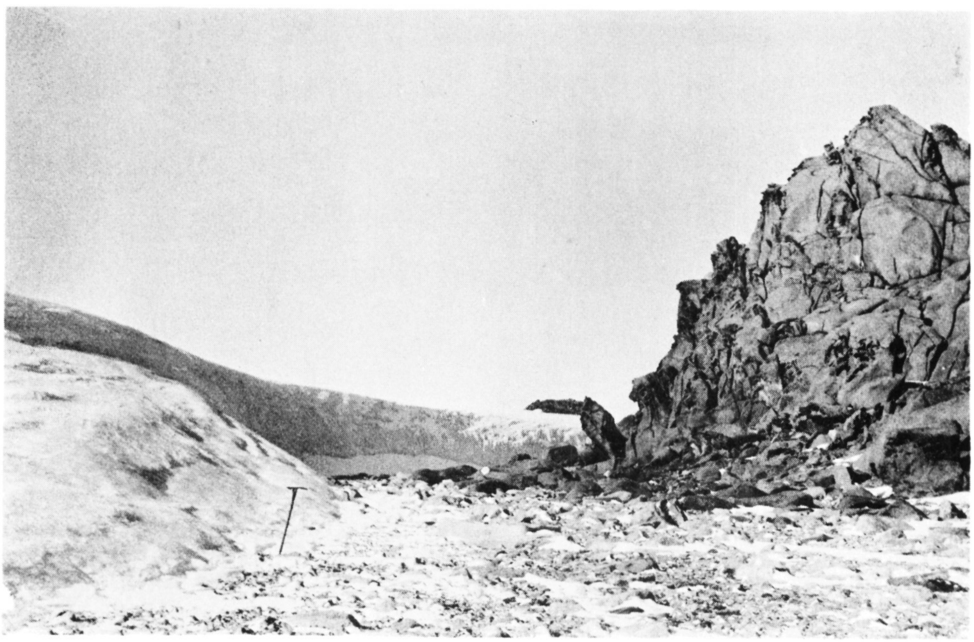


Fig. 30. Wind scoop in central Browning Island. Point 212 on right. Photograph by J. Hollin.

VII. GLACIOLOGICAL OBSERVATIONS BELOW THE SURFACE

A. BY SUBJECTS

1. Introduction

Sub-surface observations were made in all three zones of the ice sheet; firn accumulation, superimposed ice accumulation, and ablation. The discussions by subjects below are designed chiefly as introductions to the discussions by locations.

2. Wetness

The wetness of the snow in summer has been described using the subjective scale recommended by U. S. A. SIPRE (Instruction Manual No. 1). The scale has four divisions (wearing gloves):

Dry	Snowball cannot be made
Moist	Snowball can be made, but liquid water not obvious
Wet	Liquid water visible
Slushy	Liquid water can be easily pressed out

3. Hardness

Hardness values were measured (a) subjectively and (b) with the Rammsonde, again following SIPRE procedures. The subjective scale runs as follows:

Soft	Can be penetrated by the tips of four gloved (not mittened fingers)
Medium	Can be penetrated by one gloved finger
Hard	Can be penetrated by a pencil
Very hard	Can be penetrated by a knife blade

Ramm hardness values were calculated by the standard formula $R = Pnh/dx + qQ + P$, where

R = the hardness number
P = the hammer weight
n = the number of drops
h = the height of drop
dx = the penetration per "n" drops
q = the number of tube lengths
Q = the weight of one tube, all in centimeters and kilograms.

Rammsonde measurements were normally made close to the sides of the pits, but abrupt local changes in the stratigraphy may complicate the relationship of the measurements of those of density. The impression gained in the field was that ramm values would be of use in comparing absolute hardnesses in different areas, but that their stratigraphic value would be limited.

4. Density and the density of new snow
   (Hollin)

Density samples were cut with (a) SIPRE 500 cc tubes, (b) the SIPRE 75 mm auger, and (c) saws. Except when otherwise stated, the tubes were employed and were inserted horizontally into the snow. The depths quoted for density determinations are depths to the centers of the tubes, which were approximately 6 cm in diameter. The samples were weighed on SIPRE spring balances which were checked from time to time with sets of weights. The determinations should be accurate to 0.01 gm/cm^3. (All densities are in these units.)

The majority of density determinations made are reported by locations. The additional determinations below were made to help in the calculation of water equivalents for the snowfall below Mile 8:

a. Autumn 1958, at Wilkes Station

A 30 cm snowfall of original crystal forms had a density of 0.05. This was the only occasion when an appreciable quantity of settled snow was found to consist of other than rounded grains.

b. Spring 1958, between C2 and Upper Base
   (for location see Fig. 11).

Immediately below the main shear moraine large lee drifts formed during the winter of 1958. These drifts were covered in spring by a hard and slippery crust and were themselves extremely hard: too hard for density tubes to be inserted. Excavation in them was difficult since although they were too hard for a shovel they did not fracture easily (as did ice), and a pick-axe point only sank into them. Eventually they were cored to their base (the previous summer's ice) at 90 cm and the following densities measured:

6 - 31 cm	0.48
34 - 43	0.49
43 - 53	0.48

More data on this area is given by location.

c. 6 August 1958.

These densities were measured after a two week period of fine weather (sun and not much wind). Some ablation had, however, taken place during this period, since there were wind cut patterns on the snow, and the area between C1 and B13 was bare of snow.

(i) Close to BF2. At one point near here the 1958 snow (above the superimposed ice) was 38 cm deep. Nearby it was only 18 cm and a sample through the whole column had a density of 0.38.

(ii) Three pits close to F2B. Depths are to the centers of tubes. As far as possible the base of the bottom tube lay on the ice surface.

Pit 1		Pit 2		Pit 3	
3 cm	0.33	3 cm	0.31	3 cm	0.34
8	0.37	9.5	0.36	8.5	0.37
14	0.36	15	0.31	15	0.32
19	0.32	21	0.30	19.5	0.31
23	0.30	25	0.41	26	0.43
		28	0.42	29	0.42

d. 8 August 1958, three pits close to 424.

Pit 1		Pit 2		Pit 3	
3 cm	0.36	3 cm	0.41	3 cm	0.40
9	0.36	8	0.38	8.5	0.40
14.5	0.38	13	0.35	10.5	0.38
20	0.32			14	0.39
25.5	0.34				

e. 13 September 1958.

These densities were measured after a period of winds and snowfall. The area between C1 and B13 was still bare.

(i) Close to F2B

Depth:	4 cm	10	15	21	27	31
Density:	0.38	0.40	0.37	0.37	0.34	0.36

(ii) Close to S-1

Depth:	4 cm	10	15	20	24	29
Density:	0.35	0.33	0.37	0.31	0.32	0.35

Discussion

A first inspection of the above data suggests that there is no clear difference between the density of winter snow at the above locations on the lower ice sheet and that at S-2 (see S-2 by location), despite the greater average wind speed at the latter. It was clear in the field that the snow surfaces on the lower ice sheet were frequently softer and smoother than those at S-2, but the absence of a clear density difference suggests that this softer snow at the lower elevations was probably easily deflated, leaving in the long run only the harder, denser snow comparable to that at S-2.

5. Grain structure (Hollin)

A cursory inspection under a polarizing microscope of grains from the upper two meters of the firn at S-2 left the impression that the average grain comprised either two or three crystals. This is less than the "several" reported for Maudheim (Schytt, 1958). The probable cause of this discrepancy is an error in the Wilkes Station observation, but future workers may care to check this point. Concerning grain shape, nearly all the grains observed on the ice sheet could be described as sub-angular, as distinguished from rounded, sub-rounded and angular. Depth-hoar crystals were of course angular.

On the subject of grain size, if irregularly shaped grains are joined by wide bridges it is often difficult to define the boundary of any one grain, particularly under the microscope or hand lens. It seems then that the method of measuring grain size by first disintegrating a firn sample must have its limitations, since the fragments so produced may not necessarily be original grains. The method used in the studies described in this volume was that of comparing the grains *in situ* with a millimeter grid mounted on a small plastic card. In a refinement of this method, blocks were sometimes cut out of the firn and viewed next to the card against a background of strong light. Fortunately most layers in the firn appear to be composed of roughly equi-dimensional grains of one predominant size. The measurement reported is the estimated mean diameter of these predominant grains in each layer. How this estimate would compare with the results of a precise petrographic and statistical measurement of grain size is not known. However, it is believed that the estimates will compare well with those from other places since, for example, the observation that summer metamorphism of the plateau snow changes its grain size from less than to more than 0.5 mm has been made by numerous other parties also. The Wilkes measurements were normally made by Hollin, but measurements by all members of the party can be compared directly. Early in the year an estimate of the size range in a test block of firn was made by each member of the party, with the following results: Hollin, 0.8 mm to 1.2; Cronk, 0.7 to 1.15; Robertson, 0.6 to 1.05. After this test an effort was made to standardize the estimates, and these soon became indistinguishable as to author. The following common abbreviations are used throughout the report:

Very fine grain	Vfg	0 - 0.5 mm
Fine grain	Fg	0.5 - 1.0
Medium grain	Mg	1.0 - 2.0
Coarse grain	Cg	2.0 - 4.0
Very coarse grain	Vcg	> 4.0

Where grains were irregularly shaped and where the grain structure was not uniform this is mentioned in the text. The phrase "vertical structures" has been used to describe a type of firn in which vertically elongated grains are arranged in ill-defined vertical columns. This type of structure, which is probably a product of intensive and/or prolonged metamorphism near the firn surface, has been reported by various authors (Vrba and Urbanek, 1957; Stephenson and Lister, 1959).

6. "Crusts" (Hollin)

The downward percolation of summer melt water into firn produces ice layers, lenses, pipes, glands and pellets. At Wilkes Station such ice masses increased in thickness and frequency from S-2 (elevation 1166 m) down to the superimposed ice zone (upper limit 345 m). Of more doubtful origin are the much thinner ice laminae or "crusts" which were found in all parts of the ice sheet. (These are described by locations and their thicknesses given). Two major types were found: (a) thin, 0.8 mm crusts. These appeared to be composed of original snow grains weakly cemented together. (b) thicker, 1.5 to 3.0 mm crusts. These often had a sandwich-like appearance, with a fine layer of clear bluish ice between two whiter layers. In general, type (a) appears to be associated with winter snow and type (b) with snow exposed to summer metamorphism. This is however only a general observation, and at this stage neither type can be used as a seasonal indicator.

Similar rough twofold classifications of crusts have been suggested by various authors and type (a) has been described by several Antarctic workers as a "wind-crust". It is clear however that more detailed investigations will be required before any such connection between a weather element and a morphologically and crystallographically distinct type of crust can be proved. Some of the weather elements which may have to be considered as possible crust producers are wind, solar radiation, heat radiation from low clouds, the advection of warm air, rain (ordinary and supercooled) and ground-level clouds, as well as sublimation within the snow itself. In addition, it would be useful to study events at the snow surface at times when rime or glazed frost is forming on features such as stakes and buildings. Finally, it must be remembered that a crust may, after its formation, be either reinforced by melt water or perhaps disintegrated by sublimation within the snow.

It may be noted that the "wind-crusts" discussed above are not the same as the typical Alpine "wind-crusts" described by Seligman (1936). These are relatively thick hard layers. Such thicker layers do occur in Antarctica and have been described for example by Schytt (1958). Schytt does not distinguish between the thin crust and the hard layer beneath it, but Wilkes Station pit studies suggest that the 0.8 mm "wind-crust" and the thicker "wind-crust" do not necessarily occur together. The development of a thick hard layer which probably fits Seligman's and Schytt's descriptions of a wind-crust was actually observed at Wilkes Station. On 25 May 1958, at S-2, a pit was dug to 1 m.

The temperature at the time was approximately -18°C. The evening of that day was windy, and it is believed that the pit filled almost immediately with blown snow. This is a usual occurrence in Antarctic pit work, and the fill is usually so soft that somebody jumping into it sinks as if into water. However, after two days during which the temperature and wind were approximately constant at -32°C and 45 km/hr, this fill was so hard that it was almost impenetrable with a shovel. Also observed at Wilkes Station was what was probably a typical "wind-slab" as described by Seligman. This was found in the lee of the shear moraine and nowhere else in the neighborhood. It had a density of 0.48, and is described in Section VII-A-4 of the report and by locations as "Between C2 and Upper Base".

It is not possible to discuss the topic of crusts further in this report. However, this subject does deserve further research. For example, should it prove possible to distinguish types of crust which could be formed only by summer radiation, this discovery would be of great value for snow stratigraphic work. In addition to the work of Seligman and Schytt referred to above, useful discussions of this topic have been provided recently by Vickers (1958), Stephenson and Lister (1959), and Giovinetto (1960). Finally, an extensive treatment of the crust problem in Antarctica was undertaken in 1957-58 by the Soviet Antarctic Expedition at Mirny (Kotlyakov, <u>et al</u>., 1960).

7. Gas inclusions (Hollin)

Several studies have been made recently of bubble pressure and bubble chemistry in glaciers, but a description simply of bubble shape in polar glaciers appears to be wanting. The sub-surface observations of 1958 go a little way towards satisfying this need. Observations were made at most sub-surface locations of the size, shape, orientation and distribution of the bubbles in the ice. Observations were made normally with the naked eye and occasionally with an 8x lens. The descriptions given refer usually to the predominant type of clearly visible bubble, although any one piece of ice usually contains a number of types. Photographs and rubbings of several bubble types are held at The Ohio State University, but are not of sufficient quality to warrant reproduction here.

The actual observations are described by location. The types of bubbles distinguished fall roughly into three groups: (a) those produced by the densification into ice of dry firn, (b) those associated with melting, and (c) those found in the lower metamorphosed parts of the glacier. These are described briefly below:

(a) "S-2 type." Bubbles from the deep core here (see S-2 by location) resembled those illustrated by Schytt (1958), and may perhaps be considered typical of a dry firn zone.

(b) It was explained earlier that S-2 lies at approximately the upper limit of significant melting on the ice sheet. Below S-2 summer melting and refreezing produce ice masses which increase rapidly in thickness and abundance until, in the area of F2B (345 m), the whole of the firn is melted each year and the zone of superimposed ice begins.

Bubble types (b) predominate in the firn zone affected by melt and in the superimposed ice zone. In general, limited soaking of the firn produces layers of white ice which contains small crystals and small, plentiful bubbles. Intensive soaking produces layers of blue or colorless ice with large crystals and large, not so abundant bubbles. Ice with large crystals and no bubbles at all appears to be produced by the refreezing of horizontally flowing melt water. This last type of ice appears to be restricted to the superimposed ice zone, but the previous two types are found both in that zone and in the firn zone affected by melt. The distinction between these types is not rigid and, for example, white ice is sometimes associated with large bubbles, provided that these are abundant enough. All type (b) bubbles are prone to contain hoar crystals. They can be roughly classified as follows:

(i) Normal "superimposed ice type" bubbles are spherical or sub-spherical in shape, but not so uniformly distributed in the ice as types (a) and (c) (i). This commonest type of superimposed ice bubble can be divided into three sub-types:

"Limited soaking bubbles" are somewhat similar to type (a). They are normally spherical, but sometimes elongated; they are generally less than 1 mm in diameter and are evenly distributed, though a horizontal sorting inherited from the stratification of the original firn is often still visible. This type of bubble is most common in thin (e.g. 3 cm) ice layers in the firn, and in what are probably the lower parts of annual layers in the upper part of the superimposed ice zone.

"Intensive soaking bubbles" are frequently 4 or 5 mm across, and may retain their sub-spherical shape up to a diameter of approximately 10 mm. Larger sizes are usually elongated.

"Cavities." In some cases percolating melt water merely leaves an irregularly-shaped cavity in the firn or ice. Such cavities appear to be most common where melt water has run down through depth hoar layers.

(ii) "Crystal boundary" bubbles. Normally, air inclusions showed no clear relation to crystal boundaries. There were, however, two exceptions to this rule: 1. Polygonal crystals (viewed in horizontal thin sections) 1 cm across were often separated by a network of straight "polygonal" bubbles typically 1.5 mm in diameter. (See B10 by location). Perhaps these bubbles are a by-product of the exsolution of air on the initial freezing of melt water. 2. Noted in the field were long, branching bubbles which appeared to separate different crystals in the ice. This type of bubble was never studied in polarized light. It was thought to be a product, possibly, of the resolidification in late summer of ice previously disaggregated into separate crystals by the Hugi effect (Charlesworth, 1957, p. 57) and has been called a "Hugi" sub-type.

(iii) "Discoid bubbles" are discus shaped but frequently have one flat face. It was not determined whether this flatness represented a crystal boundary or a basal plane: the latter is more likely.

(iv) "Hexagonal figures" are extremely thin hexagonal, plate-like cavities, usually 1 to 2 mm across and always parallel to the basal plane of the containing crystal (this was checked on several thin sections under crossed polaroids). The largest observed was 5 mm and the smallest ones passed beyond the limit of vision. Generally the figures occurred in "flights" or clusters. Their appearance was in every way similar to that of the vapor figures plentifully illustrated by Nakaya (1956), whose publication was available at Wilkes Station. Also, their distribution was such that they could in every case have been formed by solar radiation. To confirm that they were true vapor figures and contained no air several hundred of them from different parts of the ice sheet were pierced under water. Surprisingly every figure released a bubble. These are not therefore true vapor figures, and their origin remains in doubt. The author is unaware of any other studies of similar figures by field workers, except for the interesting observations on the Ellesmere Ice Shelf by Marshall (1960), who appears to have assumed directly that his figures were vapor figures. Pending further observations and experiments the following possibilities may be discussed:

1. That the figures are the same as the hexagonal pressure cracks illustrated by Langway (1958). Both their distribution and their detailed appearance contradict this.

2. That the figures are quite normal products of freezing. However, the author has never found such figures either in fresh lake ice or in refrigerator ice.

3. That the figures are ordinary spherical bubbles transformed to this shape by migration along a thermal gradient. Again, the author has never seen such a development elsewhere.

4. That these are ordinary vapor figures which have acquired gas by diffusion. The combination of the known slowness of diffusion and of the fact that some of the figures cannot, from their situation, have been more than a few months old, makes this seem unlikely.

5. That they are the results of the thermal migration of vapor figures into ordinary air bubbles. This seems unlikely, since <u>every</u> figure yielded a bubble after piercing.

All the above hypotheses have their defects. At this stage the author feels, on the basis of their distribution, that these figures were in some way formed by solar radiation. H. Bader (private communication) has suggested that they may have been produced by a focusing of the sun's rays by already existing bubbles, which later provide the air in the figures.

(v) Hexagonal figures often grade into rounded or thicker types of figures. "Doughnuts" are small bubbles of the shape their name suggests, and appear from their distribution and from the previously mentioned work by Nakaya to have been produced by the thermal migration of hexagonal figures.

(vi) "Wirewool bubbles" are a dense network of lines of extremely small bubbles. The component small bubbles are often individually below the limit of vision. Wirewool bubbles give the containing ice a milky appearance. They were observed chiefly in ice cores, and perhaps represent very fine cracks associated with mechanical strain.

(vii) "Finger bubbles" are shaped like the fingers of a hand cupped upwards or like the calyx of a flower. They occur in horizontal layers, may have originated as depth hoar layers, and may be crystal boundary bubbles.

(viii) "Cryoconite bubbles" include firstly, the long vertical bubble produced by the downward migration of the cryoconite and secondly, lines of bubbles which radiate outwards (in horizontal planes) from the vertical bubble.

(c) Ice from the shearing zone and from Cape Folger has obviously undergone deformation near the base of the ice sheet, and the crystal fabric patterns from these areas show strong perferred orientations. Three major bubble types were observed:

(i) Small spherical or sub-spherical bubbles approximately 1 mm across.

(ii) As (i) but with one flat face in the shape of a hexagon, usually with rounded corners. The hexagonal shape distinguishes them from "discoid bubbles" (b-iii).

(iii) Bubbles elongated in the direction of flow. These were normally up to 1 cm long, but reached a length of 6 cm at Cape Folger.

Discussion of the bubble observations

a. The most obvious application of these observations is to the problem of superimposed ice stratigraphy, discussed in Section VII-A-10. Also, if hexagonal figures are in fact formed by radiation, they may be of stratigraphic value in areas with large amounts of both snowfall and melting; the figures may be concentrated in the ice masses just below the summer surfaces.

b. Secondly, the possibility may be considered of using the bubble morphology of an ice mass in the ablation zone to determine its approximate starting point in the accumulation zone. Such a determination, while less sophisticated, might be simpler than those made by bubble pressure and isotope content. If the upper part of a polar ice sheet moves rather as a block (Nye, 1959) it is possible that the distinct bubble content of, for example, the stratigraphic column at Mile 10 (Km 17), might be preserved until its emergence in the ablation zone. In fact, some evidence suggests that distinctive aspects of the bubble content may remain unchanged even by severe metamorphism of the ice. For example, if the hexagonal figures at M4 are in fact products of solar radiation, they have successfully withstood the influences of pressure, recrystallization, diffusion, and the thermal gradient for a probable travel time of thousands of years. Ultimately, of course, metamorphism can change the bubble pattern completely, producing, for example, the evenly distributed large bubbles of stop 3a at Cape Folger and the narrow clear bands of M3 and the Ramp shears. Concerning the local clear bands, these were not particularly plentiful and it is interesting to speculate on whether their apparently greater abundance in "warm" glaciers owes something to melting.

8. Dirt inclusions (Hollin)

These were of three types:

a. Sheared dirt. This can be distinguished by its concentration in shear planes and by its great size range.

b. Superimposed dirt. Dirt brought to the surface by shearing or blown onto it by wind is redistributed by summer season melt waters, and incorporated into layers of superimposed ice. The redistribution reduces the size range of this material.

c. Cryoconite. Cryoconite holes were not very plentiful at Wilkes Station. Where they did occur (chiefly near Isolated Moraine) they frequently contained dirt pellets which had a springy, elastic feel, indicative perhaps of an organic content. Similar pellets were found at depth in the Grinnell Glacier.

9. Crystallographic data (Robertson, Hollin)

Crystallographic observations were exploratory rather than directed to the solution of a particular problem: the authors felt that since they enjoyed almost the first opportunity to study superimposed and ablated ice in Antarctica their observations should be extensive rather than intensive. Crystal shape, size and orientation were measured at as many places as possible and are reported by location. A few introductory remarks are needed:

a. Shape. Crystals tended to be equidimensional. The chief exceptions to this rule occurred at C1, where the shear plane contained rod-like crystals, and at the Isolated Moraine, where disc or slab-like crystals were found.

b. Size. Unless otherwise mentioned, crystal sizes were measured under crossed polaroids on plates (thin sections) cut horizontally from the ice. To calculate the average cross-sectional area, the area of the plate was divided by the sum of all the crystals wholly on the plate and half the crystals partly on the plate. The plates were numbered and photographed (results poor) and later used for orientation work.

The largest crystals, up to several cm long, were found in the superimposed ice zone. E. Marshall (private communication) has pointed out that these crystals, of all those in the ice sheet, have spent the longest time at the melting temperature, having been near a melting surface probably for several summers. However, perhaps because this is after all a "cold" glacier, with only a thin surface zone of summer melting, no very large interlocking crystals such as those described by Bader (1951) on the Malaspina Glacier were ever noticed.

c. Orientation. Ice fabric studies were made with a Rigsby universal stage, following the procedures described by Langway (1958). Plates (thin sections) were normally taken from core samples, so that no absolute azimuth could be obtained. They were normally cut horizontally, but errors of dip of up to 10° may have developed during the coring and scetioning operations. Sectioning was begun with a saw and finished with a tea-kettle (see Langway). The variety of fabrics recorded, and their similarity from plate to plate of the same core, suggest that the tea-kettle method did not cause alternations in the sections. Sections were normally examined within a few days of collection, and relaxation is not believed to have been significant: it was noticed that sections from cryptocrystalline and strongly oriented shear zones retained the same general appearance under crossed polaroids for periods of several months.

The corrected angles from the orientation studies have been plotted on Schmidt equal-area projections (lower hemisphere). Crystals whose c-axas were oriented vertically in the field appear at the center of the projection. Horizontally oriented crystals appear at the margin of the projection, in a position dependent on their (relative) azimuth. The spacing of polar angles between the vertical and horizontal is shown on the first of the projections only (Fig. 35).

At this stage just a few remarks may be made concerning the fabrics as a whole. They fit into three simple groups. Those from S-1, B10, C2, Mitchell-Robinson and the Grinnell Glacier (3) are all from superimposed ice and are all generally random. Slight polar and equatorial concentrations may be associated with the conditions of freezing. The fabrics from M3, M4 and Cape Folger are from strongly metamorphosed ice, and, as expected, show a preferred orientation, although the girdle forms at M3 and Cape Folger are not understood. Note that the ice at M3 is probably deforming more rapidly than that at M4. (Movement data are available for this area.) The fabrics at 406 and C1 are hard to discuss in the absence of more measurements.

The second author thanks C. C. Langway for encouragement and instruction before the expedition began.

10. Stratigraphy and dating
(Hollin)

a. "Zones" of the ice sheet

The problem of where to draw the "accumulation line" or "balance line" (on a temperate glacier the "firn line") on the ice sheet at Wilkes Station was discussed briefly in Section VI-B-4-c. Usually, on a polar glacier, the zone of accumulation can be subdivided into zones of firn accumulation and superimposed ice accumulation, below which latter the zone of ablation begins. But on very cold or high polar glaciers it seems likely that the transition from the zone of firn accumulation to the zone of ablation can be made directly, without any development of superimposed ice. Such a direct transition must presumably occur when sublimation and/or deflation are capable of removing more ice in the autumn than is melted in the summer. Many of the "blue ice" areas in the Antarctic mountains must involve such a transition. It will be understood that, so long as <u>some</u> melting occurs, the two types of transition, with and without superimposed ice, may be very difficult to distinguish stratigraphically. For example, at Wilkes Station, does the ablation zone actually begin in the area of Mile 10 (467 m) and is the ice at F2B (345 m) and S-1 (262 m) ablated ice from above Mile 10; or is that ice actually accumulating superimposed ice and does the ablation zone not begin for some distance below S-1? At this stage of our investigations the combination of the sub-surface data and the stake measurements of 1958 and 1959 suggest that the second alternative is the most probable; and that a wide zone of superimposed ice exists between the approximate height limits of 345 and 230 m.

b. Annual layering

The task of identifying annual layers in the firn and superimposed ice zones is handicapped here by two factors. Firstly, very little dirt is ever blown onto the ice sheet above the shear moraine, to form stratigraphic horizons. Secondly, the relatively small accumulation is extremely variable or 'patchy' in both places and time. It was mentioned in Section VI-A-3-c that the evidence of vehicle tracks suggests that no continuous snow layers are formed between Base and S-2. In the area of the 1958 traverse, where the relief is greater than on the S-2 trail, the accumulation is clearly even patchier, and some high points may have a positive mass balance for only one year in five or ten. In such areas the boundary between two annual layers may represent several years without accumulation. Variations of accumulation in time are most important in the superimposed ice zone, where they cause the boundaries of the zone to move backwards and forwards for distances of kilometers. These variations add to the difficulty of a problem already complicated (especially in the lower part of the zone) by the large variation in the thicknesses of slush flows.

Chiefly on account of the difficulties above, no final determinations of annual layers are offered in this report. For each location there have been suggested probable and possible autumn horizons; however, these are merely the most convincing horizons in the pits and are not necessarily the only ones. In view of the extreme difficulty experienced in interpreting these pits in the field, readers are warned against making their own interpretations too readily. Until analysis is completed the conclusion from pit and stake data is that the water equivalent of annual accumulation is approximately 13 cm at S-2, 9 cm at Mile 10 and 6 cm in the center of the superimposed ice zone; the last figure being the mean of considerable fluctuations.

c. Methods of dating

A brief mention may be made of the methods which appear most likely to be useful in the final determination of annual layers. Since the accumulation is so patchy here the stratigraphy rarely shows any clear cyclic pattern of, for example, density or grain size variations. All that the investigator can do is suggest some sort of weather sequence which might have produced the plainly irregular stratigraphy. The two zones of accumulation are treated separately.

<u>The firn zone</u>

The grain size of fresh snow is usually less than 0.5 mm; grains larger than this have normally spent at least one summer near the surface. Grains grow both by long exposure at the surface during the summer and by subjection to the temperature gradients of early autumn in particular. It was noted, however, that true depth hoar crystals appeared chiefly above and below refrozen melt water layers (whatever their place in the stratigraphic column) rather than near autumn surfaces. The evidence of crusts and melt layers has been discussed in Section VII-A-6.

The superimposed ice zone

The first pits excavated in the superimposed ice zone disclosed several features of possible stratigraphic value. Blue and white horizontal layers (the color dependent on the bubble content) frequently alternated to a depth of approximately one meter, below which the contrast between them faded. The fading was probably an optical illusion, since it did not show on core samples. Bubbles and cavities were frequently distributed in well-defined horizontal lines, and excavations with a pick occasionally exposed what appeared to be old horizontal surfaces. Hexagonal figures were abundant in the ice, and occasionally showed a horizontal stratification.

The development of some of the above features was observed in the late summer of 1958, after the arrival of the year's party. It was noted that the refrozen surface of the lower ice sheet became extremely smooth, and that hexagonal figures occurred immediately below the surface. On top of the surface there developed a sort of frosting or glaze, with a honeycomb pattern of cells 1 mm or so across, of unknown origin. In the early autumn late melting and sublimation had the effect of "welding" the first new snow to the surface below to give a cryptocrystalline layer of new ice. This type of ice ("Is") is described in Section VI-B-4-b. Later in 1958, at the end of the winter, several stakes were installed and measured in various parts of the zone, with the idea of observing the full process of superimposed ice formation during the forthcoming summer of 1958-59 (see the section "Summer"). Unfortunately this project was frustrated by that summer's unusual coldness, which had the effect of leaving the whole ice sheet down to sea level still covered by winter snow. The formation of superimposed ice was observed at only one stake, in the upper part of the Ramp: by early February, 1959, the lower part of the snowpack there had melted and refrozen as white ice with "limited soaking" bubbles and no hexagonal figures. There was a very clear break between this ice and the old blue ice surface (known from the stake reading), with its "crystal boundary" bubbles and hexagonal figures. Further down the Ramp it was noticed that melt water had flowed out and refrozen as clear ice above wet and coarse snow.

On the basis of the above observations and of the stratigraphic studies, it is believed that in a normal summer there operates in the superimposed ice zone a process of increasing soaking which is outlined below. The full process is completed only at the zone's lower part; in its upper part or in a cold summer only the first stages occur. In the beginning, it appears, melt water runs to the base of the snow pack and forms a layer of white ice with "limited soaking" bubbles. If there is depth hoar at the base of snow pack "cavities" may be formed. As melting continues the upper part of the snow pack melts and may flow out over the snow or white ice below and refreeze as clear, glassy ice. If the melting is intense then the whole of the winter's snowpack may be turned to slush. Inside the slush the flow of melt water may be concentrated at the base, and freezing may leave a clear stratum at the base of the layer, the top refreezing as coarse, bubbly ice. Finally if melting is prolonged it may, after converting the whole snowpack to slush, begin to disaggregate the ice of previous years. It appears that prolonged melting of this type can disturb the crystal and bubble structure of a normally "cold" ice surface to a depth of tens of centimeters.

In conclusion, it is hoped that future workers will be more fortunate in being able to work on this problem of superimposed ice formation during a more normal summer. A possibly useful investigation would be the examination of long vertical thin sections of the ice under crossed polaroids. Such a 35 cm long section was cut at 406, but since it revealed no clear pattern the experiment was not repeated. Marshall (1960), however, on the Ellesmere Ice Shelf, had considerable success with this technique, so that a more extensive effort may be warranted at Wilkes Station. It will be understood that the problems of superimposed ice stratigraphy are most likely to be solved in the upper part of the zone, away from the considerable irregularties and unconformities which different summer conditions produce in the lower part.

11. Conductivity (Hollin, Robertson)

Measurements of the electrical conductivity of melted snow and ice samples were made with a U. S. Navy Hydrographic Office "Serfass Conductance Bridge, Direct Reading MHO-OHM Model". Concerning the reliability of this instrument, it is known to have "checked out satisfactorily" at the Hydrographic Office after the expedition's return: the exact calibration has been mislaid. The range of conductivities obtained appears to be normal for the situation.

Snow samples were collected in plastic bottles and ice samples chipped from cores. Both were melted in glass beakers, a process which incidentally displayed the crystal structure very well. To avoid the effects of preferential melting along the crystal boundaries (with their impurities), conductivity measurements were made only after each sample had completely melted. The measurements, and the temperature of the melt water at the time they were taken, are listed below in decreasing order of elevation and distance from the ocean.

Location	Depth below surface (cm)	Temp. of melt (+°C)	Conductivity (Micromhos)	Remarks
Traverse Camp D	0	24	10.3	Surface snow
S-2	~5000	8.5	5.45	1957 core
S-2	~5000	8	4.9	1957 core
BF2	640	8.5	6.7	
BF2	815	12.5	8.81	
B7	0	21	4.0	Cross-section of 1958 snow, taken 19 Nov.
S-1	0	19	12.9	Wet surface snow, Jan. 1959
S-1	300	0	7.2	
S-1	550	0	8.9	
S-1	900	0	5.5	
B10	50	10	83.0	
B10	50	19	11.8	
M3	250	11	17.7	Fairly clear ice
M3	665	11	11.4	Dirty ice
M3	1060	10	11.0	Some dirt
M4	240	9	5.42	Shear zone, as at M3
M4	290	8	16.6	Shear zone, as at M3
Upper Base-C2	250	8	30.8	Almost clear superimposed ice
C2	0	19	4.6	Cross-section of 1958 snow, taken 25 Nov. Stood 2 days after melting
Isolated Moraine	~150	11	7.5	30 cm on horizontal scale (see by location). No dirt
Isolated Moraine	~ 150	6.5	10.1	55 cm on horizontal scale
Middle Grinnell	255	23	72.9	Bubbly ice
(First series; no	760	23	86.3	Moderately bubbly ice
visible dirt; stood 10 hrs. after melting)	1090	23	120.0	Clear ice
Middle Grinnell	208	8	52.1	Bubbly, a few dirt specks
(Second series)	730	13.5	61.2	Clear, traces of dirt
	1100	11	310.0	Moderately bubbly, traces of dirt
Lower Grinnell	0	21	36.0	Cross-section of 1958 snow
Grinnell sea cliff	Sample 1	15	26.9	
(see location)	Sample 2	0	17.2	
	Sample 3	0	16.6	
	Sample 4	0	15.2	
Mitchell-Robinson sea cliff	_	8	31.0	
	_	19	17.9	
Cape Folger sea cliff	_	8.5	10.1	

The most interesting feature of these measurements is the relationship they show between conductivity and distance from the sea. Thus, in addition to the general trend for low conductivities inland and high conductivities on the Ramp (below Upper Base), it may be noted that low conductivities are also features of the ice at M3, M4, Isolated Moraine, and Cape Folger, where ice which is now near the sea actually originated in the interior and has been brought to its present position by glacier flow. Conversely, as is explained by location, the relatively high conductivity of the samples from the Grinnell and Mitchell-Robinson sea cliffs supports the argument that the ice in these cliffs is of local origin.

It was noticed in the laboratory that cryoconite pellets added to the melt water and left for several hours had no effect on the conductivity. The pattern of the measurements suggests that the chief source of the conductivity producing impurities is either the sea of the local rock. Presumably the impurities are carried inland by onshore winds which are most frequent in summer; this may explain the low conductivity of the predominantly winter snow in the B7 and C2 samples. It is hoped in the future to obtain chemical analyses of some of the returned ice samples. Clearly the influence of the sea and/or the rock is sufficient to offset any reduction of conductivity due to summer melting (Gorham, 1958), which normally occurs on the Ramp. Finally, the relative consistency of the data provides one slight argument against any large scale migration of impurities within glaciers.

12. Samples (Hollin)

The following samples are held at the Institute of Polar Studies:

a. Frozen firn and ice cores

Tube No.	Location	Depth of sample base below surface (cm)	Remarks
1	M3	532	
	M3	Shear plane	
	M3	760	
	M3	1030	
	M3	1100	
2	S-1	Unknown	
	S-1	Unknown	
	S-1	Unknown	
	S-1	367	
	S-1	704	
	S-1	1030	
	M3	425	
	M3	510	
3	S-1	Unknown	
	S-1	Unknown	

Tube No.	Location	Depth of sample base below surface (cm)	Remarks
	S-1	Unknown	
	S-1	Unknown	
	Middle Grinnell	645	Pieces broken and cemented by spittle
	Middle Grinnell	645 and 890	Chips
	Middle Grinnell	890	Pieces broken and cemented by spittle
	Middle Grinnell	1032	
4	Traverse: Dome near Camp G	12	Labelled "B"
	"	390	Labelled "B"
	"	800	Labelled "B"
	"	1000	Labelled "B"
	Traverse Camp C	60	
	Traverse Camp C	700	

On most of these samples an arrow points toward the snow or ice surface. Any lettering or numbering of the samples was done with them standing the right way up. The top of each sample is at the top of its plastic containing bag. Labels in the bags read toward the top. The bags are packed in the tubes with their tops toward the tube tops.

b. Melted snow and ice samples

These were collected in November, 1958, at B7, in the superimposed ice zone. They were melted at Base in a stainless steel container and poured into five gallon plastic bottles. This process probably involved some very slight chemical and organic contamination. Three samples were collected:

i. From a complete vertical section of the 1958 snow.
ii. From 0-15 cm below the ice surface.
iii. From 275 to 300 cm below the ice surface.

To extract five gallons of ice from this depth a hole was dug with the help of explosives. If a rough method of dating these samples can be found it should show whether B7 is an area of accumulating or ablating superimposed ice.

Firn samples for $O^{16/18}$ analysis were collected at S-2 and are described by location.

13. Cracks (Robertson, Hollin)

Cracks and crevasses had widths ranging from a few millimeters to tens of meters. Of particular interest were the vertical cracks in the essentially compressive ablation zone just east of Wilkes Station.

These cracks were plentiful and were used in pit excavations; pits were dug so that one wall was formed by a crack, whose smooth surface, possibly glazed by refrozen melt water, showed the stratigraphy much better than the other rough hewn walls. The cracks sometimes contained breccia-like fragments. The largest of them, between M1 and 403, was two or three centimeters wide. Their depth is unknown, but must be greater than the one or two meters of the pits. A core from four meters below the surface at M3 contained a crack with a glazed surface which suggested communication with the air above. None of these observations shwo whether the cracks are mechanical or thermal. Mechanical cracks might be expected to develop at right angles to the shear planes. Evidence for the existence of at least some thermal cracks was recorded by Robertson, who at 1600 hrs. on 7 April 1958, noticed a 10 minute outbreak of cracking sounds just when the sun disappeared behind clouds.

In the firn zone not even the smallest crack was observed on the trail to S-2, which argues for a compressive tendency in the ice flow along that line. The Vanderford Glacier was heavily crevassed. A crevasse at least 30 m deep was descended by Robertson, who noticed that its lowest third contained many sharply angular ice blocks. In a temperate glacier these might have been rounded off by melting. Further observations on cracks and crevasses are included in the report on the 1958 traverse.

14. Ice temperatures (Cronk, Robertson, Hollin)

a. S-1

These measurements continued directly from those of 1957, and were made with the standard Leeds and Northrup bridge, switchbox and copper-constantin thermohms as used by SIPRE. Three points need comment.

(i) No stake record of the surface level at S-1 is available for the summer 1957-58. However, at the end of the 1957 winter 20 cm of new snow covered the old ice surface in which the thermohms were originally installed. When this area was visited by the 1958 party on 27 January 1958, the surface was slush, but on 3 February 1958 had changed to ice. Since this area is normally well within the superimposed ice zone it can safely be assumed that the 3 February ice was frozen fresh slush rather than ablated ice from a previous year. This assumption is supported by pit observations which show that the surface ice here was very coarse and bubbly and had a density of only .76. Ice of this low density appears to last only one year, since in the following year melt water fills most of its cavities and brings the density up towards 0.9. To conclude, assuming for the 20 cm of new snow a density of 0.4, by the end of the 1957-58 summer the surface relative to the thermohoms was somewhere between 0 and 8 cms higher than it was at the time of emplacement. The change in surface level throughout the rest of 1958 is summarized in Section V-A-3.

(ii) During the 1957-58 summer the thermohm at the surface in 1957 melted its way into the ice to an unknown depth, probably less than 30 cm. Readings were, however, continued on this thermohm until its failure late in May for an unknown reason. Because of the danger of damaging the other thermohm leads it was not considered worthwhile to dig it out. Pending analysis, the few positive readings on this and the 50 cm thermohm are probably due to the absorption of radiation from the sun.

(iii) In this apparatus the checkpoint, embodied in the switchbox, was a standard resistor designed to read -2.0 ± 0.2°C. In fact the reading on the checkpoint was usually out by a few tenths of a degree and on occasion by as much as 1.6°. On these occasions of large error a similar irregularity was also found in the deep thermohm readings. Temperature changes at 16 m depth are clearly slow, and readings 1.6° different and only one week apart are obviously incorrect. The similarity of the larger errors in both the checkpoint and the deep thermohms suggests that the cause was a bad contact at some point on the bridge side of the switchbox. For the purpose of analysis it is suggested that the 16 m temperature be plotted for the year and that deviations from it greater than the reading accuracy of 0.05° be applied as corrections to all the readings of the weeks concerned. If these corrections are made it will probably be found that most errors in the checkpoint reading then fall within approximately the 0.2° allowed by the manufacturers. Any larger errors remaining are probably the result of contact errors impossible to analyze and of very low temperatures in the resistors and wiring of the switchbox and bridge. These remaining errors can be used to calculate the limits of accuracy of the final figures.

The measurements which follow are in minus degrees centigrade, except for the few positive cases noted. Gaps in the record occur when the bridge was being used elsewhere, as on the traverse.

S-1 ICE TEMPERATURES

Date	Time	0 (Check)	Ice Surface	Switch Positions 1 1/2m	2 2m	3 4m	4 7m	5 11m	6 16m
1958									
27 Jan.		2.04	+ 0.61	+ 0.21	3.20	6.84	8.33	7.98	7.67
3 Feb.		2.00	+ 0.30	+ 0.20	2.20	6.10	8.10	8.00	7.60
10 Feb.		2.00	+ 0.23	+ 0.32	2.02	5.95	7.95	7.95	7.60
17 Feb.		2.03	+ 0.26	+ 0.12	1.98	5.51	7.78	7.94	7.61
24 Feb.		2.04	1.01	0.41	2.20	5.47	7.76	7.99	7.69
3 March		2.01	2.30	1.19	2.62	5.19	7.58	7.96	7.61
10 March		2.01	4.00	2.35	2.93	5.00	7.39	7.90	7.66
17 March		2.00	4.60	4.20	3.80	5.10	7.15	7.80	7.60
24 March		2.08	3.04	4.71	4.40	5.25	6.99	7.83	7.62
31 March		2.04	7.35	5.91	4.50	5.22	6.92	7.78	7.61
4 April		2.15	7.60	6.70	5.50	5.50	6.85	7.75	7.65
14 April		2.00	6.35	6.20	5.80	5.60	6.80	7.80	7.70
21 April		2.20	11.20	8.95	6.05	5.75	6.65	7.60	7.60
28 April	1030	2.20	8.25	8.30	7.40	6.00	6.70	7.60	7.65
5 May	1100	2.20	11.39	10.22	7.62	6.40	6.81	7.62	7.68
12 May	1200	3.00	9.82	10.81	7.53	7.75	7.78	8.50	8.79
19 May	1045	2.01	6.51	7.59	8.20	6.99	6.81	7.58	7.62
26 May	1100	2.21	10.22	10.15	8.18	7.43	7.24	7.82	7.99
2 June	1100	2.39		11.83	8.81	7.39	7.10	7.59	7.71
9 June	1115	2.41		13.59	10.03	7.54	7.10	7.42	7.63
16 June	1100	2.30		16.18		7.99	7.16	7.50	7.70
24 June	1230	2.59		16.83	12.18	8.24	7.18	7.41	7.60
1 July	1400	2.21		18.80	13.95	8.80	7.27	7.40	7.60
9 July	1030	2.19		15.00	14.03	9.55	7.50	7.42	7.61
14 July	1200	2.20		13.13	13.20	9.81	7.55	7.33	7.51
21 July	1130	2.20		12.50	12.50	10.10	7.75	7.45	7.60
28 July	1100	2.27		13.60	12.17	10.05	7.81	7.30	7.41
4 Aug.	1100	2.22		14.78	12.60	10.20	8.00	7.40	7.60
11 Aug.	1100	2.35		15.65	12.95	10.30	8.18	7.45	7.60
19 Aug.	1205	2.05		15.55	13.62	10.45	8.30	7.48	7.55
25 Aug.	1200	2.25		15.00	13.55	10.77	8.43	7.58	7.58
2 Sept.	1200	2.20		14.40	13.55	10.95	8.60	7.60	7.55
8 Sept.	1200	2.90		15.60	14.10	11.90	9.60	8.50	8.40
15 Sept.	1205	3.60		17.20	14.80	12.40	10.10	8.90	8.80
17 Nov.	1015	2.68		11.79	12.86	12.48	10.52	8.77	8.04
24 Nov.	1530	2.20		10.38	11.65	11.72	9.95	8.19	7.70
8 Dec.	1500	2.15		8.85	10.43	11.20	9.92	8.21	7.65
29 Dec.	1540	2.10		6.25	8.60	10.37	9.82	8.32	7.61
1959									
6 Jan.	1200	2.02		5.95	7.98	9.87	9.70	8.35	7.60

b. The S-2 trail

As a supplement to the work of 1957, temperatures were taken at approximately 10 m depths at additional points on the S-2 trail. A portable SIPRE thermohm and the Leeds and Northrup bridge were used for these measurements. Their accuracy can be calculated by reference to Section a-iii above, and by inspection of the check point errors at S-1 in the periods concerned.

In June, 1958, a hole 11 m deep was drilled for various purposes in the ice approximately 50 m north of the fixed thermohms at S-1. Comparative measurements in the two holes are given in minus degrees centigrade. Hole temperatures took approximately 2.5 hours to stabilize.

	14 June	16 June	18 June	19 June	20 June	24 June
S-1 check point	2.35	2.3	2.25		2.53	2.59
Air temperature ~ 20 cm above surface	21.0		16.0	23.0	27.0	
Old hole 4 m	7.6	7.16	7.2	7.99	8.19	8.24
7 m	7.1	7.5	7.4	7.1	7.23	7.18
11 m	7.4	7.7	7.7	7.99	7.53	7.41
16 m						7.6
New hole	6.95	7.16	7.05	7.1		7.4
Depth (m) of new hole at the time	7.0	8.5	8.5	?		11.0

Temperatures measured at other locations during 1958 were:

	Elev.	Depth	Date	Temp. (-°C)
Middle Grinnell	36 m	11 m	7 Aug.	7.8
			8 Aug.	7.6
			15 Aug.	7.75
M3	157 m	9 m 90	20 Aug.	7.75
		11 m	21 Aug.	7.75
BF2	381 m	11 m	25 Aug.	10.55

Since these temperatures are from depths where the range of the annual temperature wave is still of the order of 1°C, they should be reduced to a common time of year before being compared. The fuller data from S-1 can be used for this reduction.

A comparison of these preliminary figures with those given in the Report for 1957, shows how the relationship between average air temperatures and 10 m subsurface temperatures breaks down in the superimposed ice and ablation zones. Several factors complicate the temperature distribution in these lower zones. The superimposed ice zone is warmed in autumn by the refreezing of stagnant slush and the release of its latent heat. The ablation zone loses heat by the runoff of melted material and by the truncation by melt of the upper warm part of the temperature wave. At M3 the advection of shearing cold ice and warming by internal friction may be significant. In both zones autumn snow, as it settles, reduces by its high albedo the radiation absorbed.

Two more observations are included here. Firstly, at least two melt tunnels were observed in the ablation zone, leading from a rock and ice girdled hollow near nunataks 214' and 218' on Browning Island (H.O. Chart 6658). These tunnels were not explored, but appeared to be confined to the upper meters of the ice. Secondly, at no place were streams observed emerging from tunnels below the ice sheet. However, no particular search was made for these, and in this section of the report the author offers no opinion on the basal temperatures of the local ice sheet (see Section IV-B).

c. In pits

Pit wall temperatures were recorded using the Weston dial thermometers issued by SIPRE. These were checked from time to time and were always accurate to within ± 1°C.

15. Introduction to (B)
(Hollin)

Observations by location are arranged in order of decreasing height and distance from the coast, from the interior station at S-2 down to sea level. Those in the firn zone are limited in number and are merely supplementary to those of 1957. Except for the special case of the traverse of 1958, observations in the firn and superimposed ice zones were confined to the S-2 trail. Because this has such a regular profile the observations along it provide an ideal cross-section of the ice sheet margin. It must be remembered however, that this ideal section is not very typical, and that over most of the Antarctic margin irregular topography is the cause of a very patchy pattern of accumulation and ablation. Observations in the ablation zone at Wilkes Station were made both on the S-2 trail and on the ice sheet for several kilometers north and south of the station.

Observations were normally made in pits or on cores secured with the SIPRE 75 mm auger. In the firn zone pits a whisk broom was used to accentuate the stratigraphy. Pits in the ice of the superimposed ice and ablation zones were excavated using a single-pointed Steuri type pick, as described by Bader (1951). This pick worked incomparably better than any other excavating tool, and was the most valued item of glaciological equipment at the station.

Observations in the firn zone are presented with the aid of pit diagrams. Times given are Local (7 hours behind Greenwich "Z"), and are the times at which the temperatures were taken. Unless otherwise marked, the firn was all old, fine or medium grained (less than 2 mm) and sub-angular. "Old, angular, coarse" snow often included sublimation crystals. Crusts (3 mm or less) are indicated by single fine lines and are described in more detail in the accompanying texts. Ice layers are indicated by lines to scale, and are also described in the texts. Intermittent crusts and layers are indicated by dashed lines. The diagrams illustrate what was felt in the field to be the most typical section of the pit walls. Probable autumn horizons are marked "<" and possible ones "<?". Terms used in the text have been explained by subjects. In particular, "vertical structures" are described in Section VII-A-5, and bubble types in Section VII-A-7. "Layer" is synonymous with "stratum"; "surface" with "break" and "horizon". The "total" thickness of an ice layer is its average thickness on all the pit walls and the "local" thickness its maximum thickness at any one point on the walls.

Finally the author, Hollin, who is responsible for most of the observations by location, would like to point out that few of them could have been made without the strength and enthusiasm of Casper Cronk and Richard Robertson, who worked extremely hard at the tedious task of excavating and coring samples from so many locations in solid ice.

B. BY LOCATIONS

LOCATION S-2 ELEVATION 1166 m

1. Notes on the pit diagrams

PIT 1 (20 May 1958)

The shade temperature at 1700 Z was $-8.5^{\circ}C$. This excavation followed more than 12 days of 50 km/hr winds and temperatures higher than $-20^{\circ}C$, latterly up to $-7^{\circ}C$. The rammsonde data was taken several meters away on 15 April, so cannot be compared directly with the pit data.

Stratigraphy

cm	
0-6	Fresh snow
6-13	Fresh snow. Bedding visible under artificial light.
13-16	Faint crusts
18-20.5	Three undulating crusts (< 0.6 mm) and a possible ice pellet. Coarser snow between the crusts.
21-33	Very fine grained and hard
33-34	Up to three thin, intermittent crusts with soft, coarse snow best developed between the bottom two.
67-70	Up to five crusts up to 3.0 mm thick. One thickens locally to 1.5 cm and one ice pellet was found. Crusts rise and fall to meet each other and on the south wall occupy a maximum vertical interval of 14 cm. Coarse, loose snow between the crusts.

73-125	Vertical structures above 102 and below 119 cm. 86-88 and 119-121: many grains 3 mm across.
126	Depth hoar crystals up to 5 mm across
148	Five crusts with coarse, sometimes very soft firn between them
205-206	A not very well marked coarse layer
207	Crusts up to 6 mm thick
207-212	Moderately coarse.

Note

In several excavations in this area Cronk noted that the upper 18 cm of this stratigraphy could disappear laterally, leaving the 18 cm crusts at the surface.

PIT 2 (16 November 1958)

Temperatures at 1100 hrs

10 cm above the surface (shade)	- 7°C
On the surface (shade)	-10°C
On the surface (in the sun)	0.75°C

Stratigraphy

cm	
0-44	Homogeneous firn, grain size 0.3 - 0.4 mm, with an intermittent undulating crust at 9 cm
44-54	A distinctive hard layer, probably the same as the 21-33 layer in PIT 1. Grain size 0.3 mm. Too hard for density tubes.

PIT 3 (10 January 1959)

Temperature at 1500 hrs

5 cm above the surface (shade) 0°C

None of this snow formed snowballs.

Stratigraphy and interpretation

cm	
0-8	Crusts probably formed in the current summer
8-31	Winter snow
31-50	Probably the distinctive hard layer of PITS 1 and 2.
52	At least three crusts, one 3 mm thick with a sandwich like appearance. Grain size begins to increase below this horizon, which probably marks the 1957-58 summer.
52-113	Apparently homogeneous firn, with crusts (< 1 mm) at 59, 69 and 102. On one wall the crust at 59 has been reinforced by melt water and consists of 2 or 3 mm of clear ice. An ice pellet was observed on one wall of the pit.

113	Three adjacent crusts sometimes total 5 mm in thickness. This may be the same horizon as 70 in PIT 1.
113-133	Coarse layers, most marked between 117 and 127.5. Grains at that depth are 3 mm across but do not include any depth hoar. This stratum probably marks the summer of 1956-57.
139	Several thin crusts, with one ice gland forming at 130 and running down to 150. These laminae may represent the summer of 1955-56.
139	Well developed depth hoar crystal up to 5 mm across.

The average of all stake measurements in the S-2 area shows an accumulation of 15 cm of snow between March, 1957, and January, 1958, and 50 cm of snow between January, 1958, and January, 1959. These figures support the interpretation of 52 as the 1957-58 summer horizon, but leave the position of the 1956-57 horizon uncertain. There may have been a heavy snowfall early in 1957, before the arrival of the glaciological party. A summer horizon may occur in the pit somewhere between 52 and 113, but no trace of it could be seen by the observers.

Samples for $O^{16/18}$ study

Samples of firn for oxygen isotope studies were cut from the walls of this pit at the following depths: 3, 8, 18, 24, 31, 36, 43, 50, 54, 59, 64, 69, 76, 83, 90, 96, 102, 108, 113, 120, 127, 135, and 139 cm. These samples are numbered 1-23, No. 1 at the top. They are currently held by Dr. R. Sharp at the California Institute of Technology, Division of Geological Sciences.

2. Densities of cores drilled at S-2 on 29 January 1959, in connection with a density logging experiment by M. Mellor

Interval (cm below surface)	Density
91 - 100	.44
177 - 200	.45
268 - 300	.47
368 - 400	.47
464 - 500	.51
565 - 600	.55
641 - 660	.57

3. Crystal and bubble observations

Half the cores extracted from the 36-62 meter drill hole at S-2 were returned to the U. S. by the 1957 party, but the remainder are in boxes in the S-2 laboratory. The following observations were made on these during 1958:

Core 102 ($\sim$58.4 meters)

(i) The average cross sectional area of 315 crystals in a horizontal section was 3.8 mm^2. The largest crystals were 3-4 mm long, but the crystals as a whole were equidimensional.

(ii) Bubbles were typically cylindrical, 0.5 mm in diameter and 1-2 mm long. More long bubbles were seen in a vertical than in a horizontal section, so that the original firn may have included vertical structures.

Core 104B ($\sim$58.9 meters)

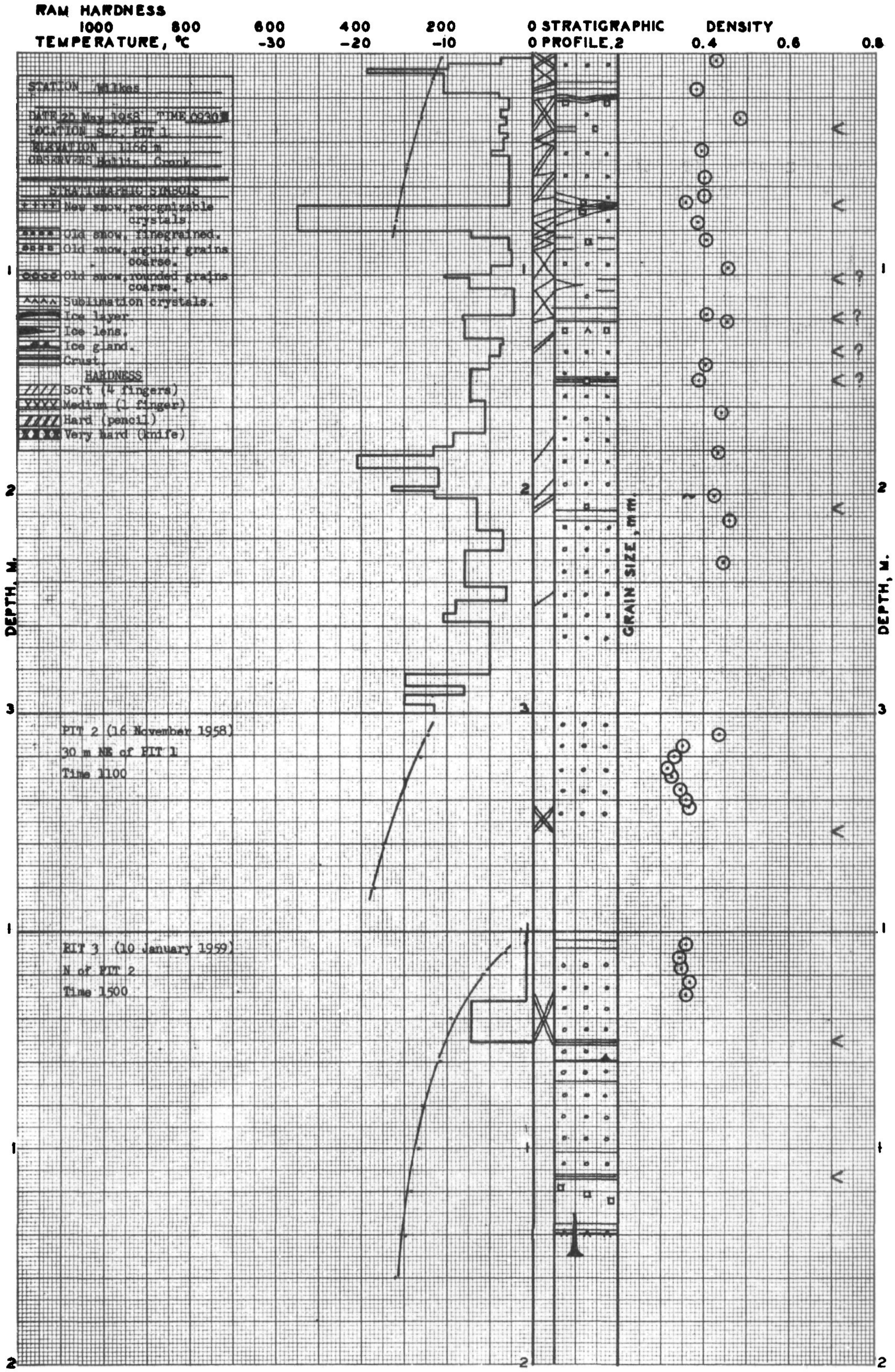
(i) This was sectioned vertically. The crystals appeared equidimensional. The section included a 0.8 mm crust. This was just discernible in the crystal pattern and seemed to show a preferred extinction.

Core 112B ($\sim$59.8 meters)

A section from this core was used to check out the Rigsby stage and its operator. The fabric determined has not been recorded, but certainly showed no strong pattern.

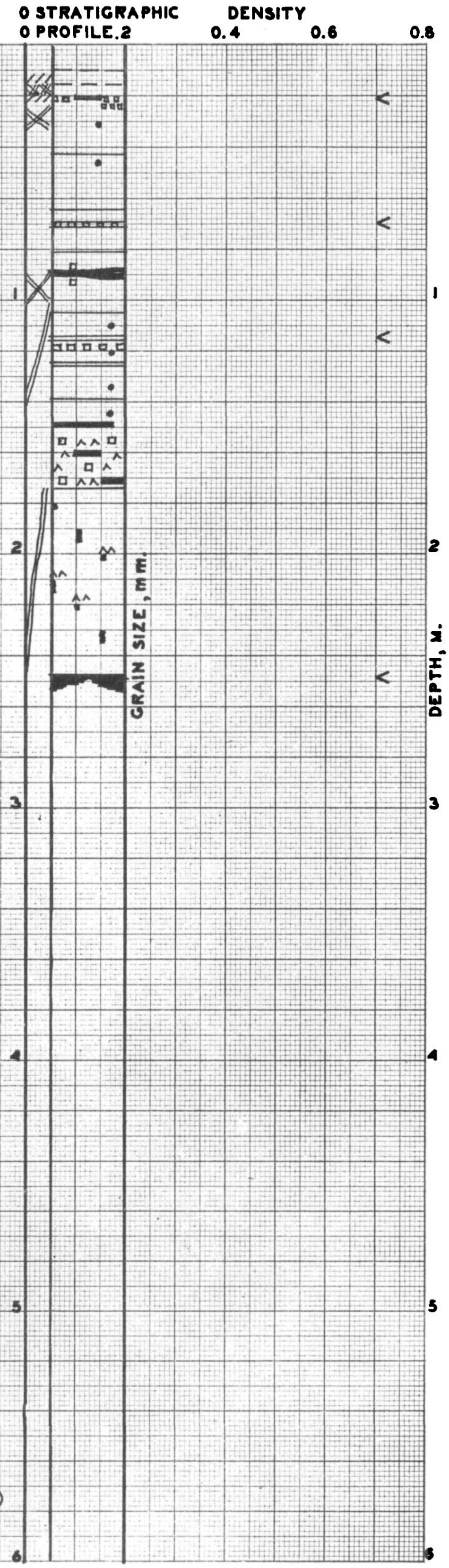
Hexagonal figures

None was seen in any of the cores.



RAM HARDNESS
1000
800
600
400
200
TEMPERATURE, °C
-30
-20
-10
0 STRATIGRAPHIC
0 PROFILE .2
DENSITY
0.4
0.6
0.8
STATION Wilkes
DATE 25 May 1958 TIME 0930
LOCATION S-2, PIT 1
ELEVATION 1166 m
OBSERVERS Hollin, Cronk
STRATIGRAPHIC SYMBOLS
New snow, recognizable crystals.
Old snow, finegrained.
Old snow, angular grains coarse.
Old snow, rounded grains coarse.
Sublimation crystals.
Ice layer.
Ice lens.
Ice gland.
Crust.
HARDNESS
Soft (4 fingers)
Medium (1 finger)
Hard (pencil)
Very hard (knife)
DEPTH, M.
GRAIN SIZE, mm.
PIT 2 (16 November 1958)
30 m NE of PIT 1
Time 1100
PIT 3 (10 January 1959)
N of PIT 2
Time 1500

RAM HARDNESS
1000 800 600 400 200 0
TEMPERATURE, °C -30 -20 -10 0



STATION Wilkes (S-2 trail)
DATE 31 May 1958 TIME Z
LOCATION Mile 40 (Flag 2)
ELEVATION 1016 m
OBSERVERS Hollin, Cronk

STRATIGRAPHIC SYMBOLS
- New snow, recognizable crystals.
- Old snow, finegrained.
- Old snow, angular grains coarse.
- Old snow, rounded grains coarse.
- Sublimation crystals.
- Ice layer.
- Ice lens.
- Ice gland.
- Crust.

HARDNESS
- Soft (4 fingers)
- Medium (1 finger)
- Hard (pencil)
- Very hard (knife)

SHADE TEMPERATURE 5 cm above surface
-29°C at 1430 hrs.

STRATIGRAPHIC RECORD

cm	
0.0-10.0	New snow. Bedding visible.
10.0-15.0	Possible wind crusts, with a soft layer up to 2 cm thick above the bottom one.
15.0-20.0	Hard and very fine grained.
20.0-21.5	Coarse angular firn above a possible wind crust. On one wall of the pit this stratum is 5 cm thick and has 1 cm of ice in the middle.
21.5-25.0	Coarse firn.
25.0-31.0	Hard. Ice pellet at base.
31.0-42.5	Medium grained, with a possible wind crust at the base.
42.5-68.0	Homogeneous firn, coarser upwards. Ice pellets and possibly a truncated ice pipe at 46. Possible wind crust at 64 is not thickened by melting.
70.0	Two possible wind crusts (no sign of melting), with coarse angular grains between them.
70.0-88.0	Medium firn with vertical structures, slightly coarser above a probable wind crust at 81.
88.0-90.0	Interfingered coarse angular firn and ice layers up to 3 cm thick.
90.0-101.0	Hard to very hard firn.
101.0-148.0	Medium to hard firn, coarser and softer at 110.0-113.5 and particularly at 117.0-118.5, with possible wind crusts at 105, 114, 115, 124, 126 and 138. The crust at 114 may have been thickened by melt. On one wall of the pit this whole section includes ice pellets.
148.0-174.0	Ice layers interfingered by depth hoar and coarse angular firn. Upper layers are mostly continuous and up to 2 cm thick. Depth hoar, with crystals up to 8 mm across, occurs in irregularly shaped masses.
174.0-248.0	Homogeneous hard firn, with ice pellets and intermittent ice lenses up to 5 cm thick with depth hoar above them. But these ice lenses are isolated, and other parts of the pit wall show no trace of summer.
Below 248.0	Ice layers.

DISCUSSION

This pit lies on a part of the trail where the surface angle is less than normal, so that conditions may be favorable for a slightly heavier accumulation than elsewhere.

BUBBLES

As for Mile 30 (core taken on same day with same results.)

RAM HARDNESS 1000 800 600 400 200 0

TEMPERATURE, °C -30 -20 -10 0

STRATIGRAPHIC PROFILE 2

DENSITY 0.4 0.6 0.8

GRAIN SIZE, mm.

DEPTH, M.

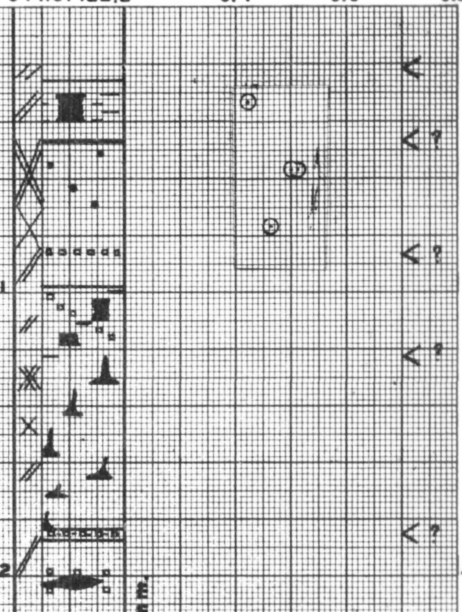
STATION Wilkes (S-2 trail)
DATE 14 July 1958 TIME Z
LOCATION Mile 30 (Flag 4)
ELEVATION 861 m
OBSERVERS Hollin, Robertson

STRATIGRAPHIC SYMBOLS

- New snow, recognizable crystals.
- Old snow, finegrained.
- Old snow, angular grains coarse.
- Old snow, rounded grains coarse.
- Sublimation crystals.
- Ice layer.
- Ice lens.
- Ice gland.
- Crust.

HARDNESS

- Soft (4 fingers)
- Medium (1 finger)
- Hard (pencil)
- Very hard (knife)



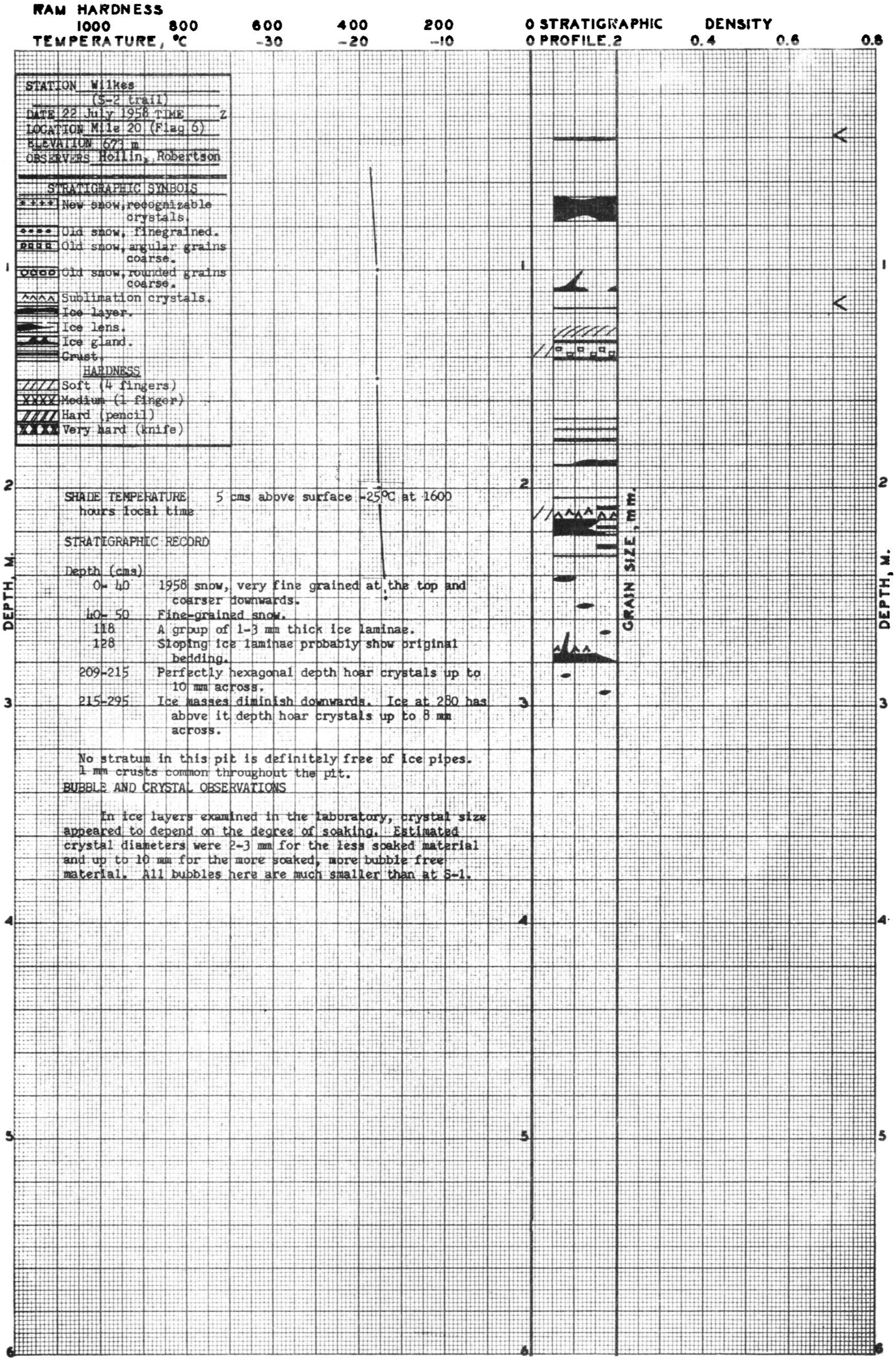
SHADE TEMPERATURE 5 cms above surface -21.5°C at 1800 hours local time

STRATIGRAPHIC RECORD (pit examined by artificial light on 14 July and in bad light and blowing snow on 15 July)

Depth (cms)	
0- 25	1958 snow, soft at base.
25- 26	Ice layer up to 1 cm thick.
26- 46	Intermittent ice layers, up to 10 cms thick.
46- 47	Continuous ice layer up to 1 cm thick.
47- 70	Very hard snow, possibly soaked. A few ice pellets.
98	Almost continuous ice layer up to 1 cm thick.
98-122	Intermittent ice layers up to 4 cm thick, interfingered by hard snow and very coarse snow, the last above and below ice layers and with many grains 5 mm in diameter.
122-175	Upper very hard snow is probably soaked. Medium snow below this has probably been exposed to summer metamorphism.
185	Fairly continuous ice laminae, interfingered by coarse snow.
185-200	Possibly soaked.

BUBBLES (75 mm core to 1 m taken here on 16 November 1958)

Ice layers inspected held a dense network of interconnecting small bubbles in the shape of bent and deformed cylinders. Several discoid bubbles, but no hexagonal figures seen in the poor light.



SHADE TEMPERATURE 5 cms above surface -25°C at 1600 hours local time

STRATIGRAPHIC RECORD

Depth (cms)	
0- 40	1958 snow, very fine grained at the top and coarser downwards.
40- 50	Fine-grained snow.
118	A group of 1-3 mm thick ice laminae.
128	Sloping ice laminae probably show original bedding.
209-215	Perfectly hexagonal depth hoar crystals up to 10 mm across.
215-295	Ice masses diminish downwards. Ice at 280 has above it depth hoar crystals up to 8 mm across.

No stratum in this pit is definitely free of ice pipes. 1 mm crusts common throughout the pit.

BUBBLE AND CRYSTAL OBSERVATIONS

In ice layers examined in the laboratory, crystal size appeared to depend on the degree of soaking. Estimated crystal diameters were 2-3 mm for the less soaked material and up to 10 mm for the more soaked, more bubble free material. All bubbles here are much smaller than at S-1.

RAM HARDNESS 1000 800 600 400 200 0

TEMPERATURE, °C -30 -20 -10 0

STRATIGRAPHIC PROFILE

DENSITY .2 0.4 0.6 0.8

GRAIN SIZE, mm.

DEPTH, M.

STATION Wilkes (S-2 trail)

DATE 1 August 1958 TIME ____ Z

LOCATION Mile 10 (Flag 8)

ELEVATION 467 m

OBSERVERS Hollin, Robertson

STRATIGRAPHIC SYMBOLS

- New snow, recognizable crystals.
- Old snow, finegrained.
- Old snow, angular grains coarse.
- Old snow, rounded grains coarse.
- Sublimation crystals.
- Ice layer.
- Ice lens.
- Ice gland.
- Crust.

HARDNESS

- Soft (4 fingers)
- Medium (1 finger)
- Hard (pencil)
- Very hard (knife)

STRATIGRAPHIC RECORD

cm	
0.0-20.0	1958 snow (grain size 0.3 mm). Softer at the bottom.
20.0	Intermittent 2 mm ice lamina (melt crust?). Intermittent 3 cm of icy snow.
20.0-41.0	Snow (grain size < 1.0 mm), finer and harder below 36, but with coarse patches and ice, locally 3 cm, total 2 cm.
41.0-51.0	Ice, locally 16 cm, total 8 cm. Bubbly at top, blue beneath. Split into several layers on two walls of pit. Possibly more hexagonal figures in the lower part.
51.0-60.0	Soaked firn (grain size ~ 3.0 mm), coarsest where ice above is thin.
60.0-65.0	Ice, locally 10 cm, total 5 cm.
65.0-73.0	South wall of pit: coarse angular grains above a less than 1.0 mm crust, above firn with a grain size of 1.0 mm. Other walls: Firn (grain size 2.0 mm at the top and 1.5 mm at the base).
73.0-93.0	Ice, connected to that above by pipes. This ice is blue above 79, but changes sharply there to white ice with large bubbles and more plentiful hexagonal figures. Below this the ice becomes bluer again. On two walls of the pit the break at 79 is represented by a 1 cm layer of compacted coarse firn. A rubbing of one section of the pit wall between 75 and 95 cm is held at The Ohio State University.
93.0-99.0	Firn, locally 15 cm. Grain size in the center of this layer averages 1.5 to 2.0 mm. The top of the layer is coarser, with vertical structures and cavities. At the base an irregular layer of depth hoar.
99.0-107.0	Ice, locally 12 cm, total 6 cm.
107.0-111.0	Probably soaked depth hoar. Water appears to have run over the hoar crystals, rounding them in the process, and onto the layer below.
111.0-123.0	Ice, still showing some firn bedding.
123.0-127.0	Firn, locally 10 cm.
127.0-139.0	Ice, total 15 cm. At 130 cm a line of 5 mm diameter bubbles with firn inside them.

DISCUSSION

In this area summer melt water is almost certainly running down onto and thickening ice masses from the previous year.

BUBBLE AND CRYSTAL OBSERVATIONS

In ice from the 41-51 stratum, studied in the laboratory, several crystals had diameters over 1 cm. Crystal areas appeared smaller in horizontal sections than in vertical. Crystal boundary bubbles were observed.

RAM HARDNESS
1000 800 600 400 200 0

TEMPERATURE, °C
-30 -20 -10 0

STRATIGRAPHIC PROFILE

DENSITY
.2 0.4 0.6 0.8

STATION Wilkes
(S-2 trail)
DATE 4 August 1958 TIME ____ Z
LOCATION BF2
ELEVATION ~381 m
OBSERVERS Hollin

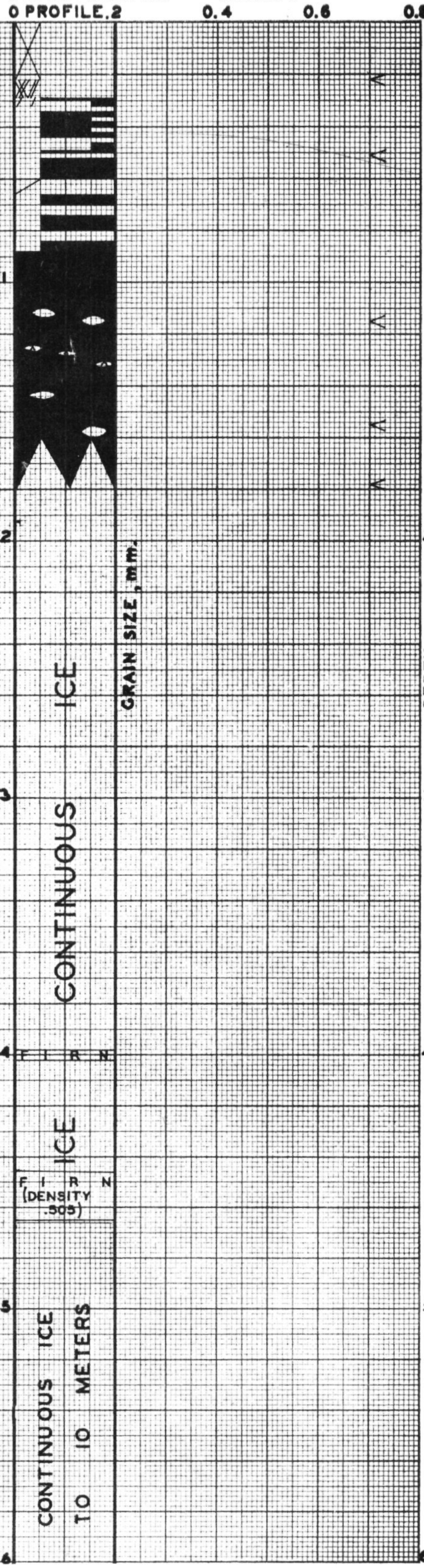
(Pit to 183 cm, 4 August 1958
Core to 1000 cm, 23 August 1958)

STRATIGRAPHIC SYMBOLS

- New snow, recognizable crystals.
- Old snow, finegrained.
- Old snow, angular grains coarse.
- Old snow, rounded grains coarse.
- Sublimation crystals.
- Ice layer.
- Ice lens.
- Ice gland.
- Crust.

HARDNESS

- Soft (4 fingers)
- Medium (1 finger)
- Hard (pencil)
- Very hard (knife)



DEPTH, M.
1 2 3 4 5 6

STRATIGRAPHIC RECORD

Depth (cms)	
0- 29	1958 snow. Grain size less than 0.5 mm.
29- 50	Soaked snow and ice layers, locally 10 cms, total 12 cms.
50- 52	Intermittent coarse firn layers.
52- 60	Blue ice, possibly an autumn surface at the top. One speck of dirt at 52, below firn.
60- 88	Alternating firn and ice layers, with good depth hoar at 71-73, above the main ice layer. On one wall of the pit these layers number only two: sporadically soft firn above and ice below.
88- 100	Blue ice, usually with ice free firn just above it.
100- 110	White ice.
110- 115	Blue ice. Cavities at 112.5 and 115.0 cms.
115- 145	Generally white ice. A possible autumn surface at the top. Cavities filled with hoar between 125 and 133 cms.
145- 183	Ice. Possible autumn surfaces at 145 and 158. Both surfaces have cavities above. The stratum 145-158 is clearer at the top. Big bubble horizons at 171 and 183 cms.
183-1000	Continuous ice except for bands of icy firn at 400 and less icy firn at 455 cms.

BUBBLE AND CRYSTAL OBSERVATIONS

Cores from the 10 m hole here broke continuously into small lengths. Horizontal sections of a core from 670, viewed under crossed nicols, consisted of regularly polygonal crystals of roughly equal size. Air inclusions were concentrated at crystal boundaries in the form of long, branching bubbles. Inside the crystals hexagonal figures were plentiful.

LOCATION   Between BF2 and F2B   ELEVATION 381 m to 343 m

Observer: Cronk

A series of pits dug between 16 and 19 July 1958

1. (S9) (377 m)

cm	
0-18	New snow, with ice lamina at base
18-24	New snow, grain size 0.5 mm
26	A layer of ice which still shows traces of original snow grains
28	Depth hoar with signs of soaking. Grain size 0.5 to 0.7 mm
29	Ice layer. Well-defined upper surface with hoar crystals bonded to it. Lower surface irregular and grades into the firn below.
29-35	Firn. Grain size ~ 1.0 mm
36	Ice layer, similar to 29.
36-37.5	Firn. Grain size 1.0 - 1.3 mm. Grains bonded to ice above.
38.5	Locally an ice layer.
39	Locally coarse firn.
110	(39-100 sounded only by 1" auger) Ice, broken by softer strata at 62.5-78.0, 82.0-84.5, and possibly 99 and 110.

2. (B3) (366 m)

cm	
0-6	New snow
6-14	A mixture of coarse firn, soaked firn (well cemented but grains distinct) and ice. The last two grade into each other and are roughly arranged as three bands 1-2 cm thick separating four layers of the coarse firn but nevertheless connected by glands.
14-19	Soft firn. Grain size ~ 1.0 mm, the bottom well bonded to the ice below.
19-100	Almost blue ice at the top. No softer strata detected by auger.

3. (S8) (351 m)

cm	
0	Ice surface
0-14	Ice between 4 and 14 cms thick, normally split into layers interfingered by soaked coarse firn. Ice layers have a varying air content and some look like melt reinforced crusts.

14-16	Less cohesive firn.
Below 16	Almost blue ice.

4. (Midway between S8 and F2B) ($\sim$347 m)

cm	
0-11.5	Soaked firn and ice glands and layers. In some parts of the pit 2 cm of depth hoar below 9.5.
11.5-17	Ice with $\sim$ 1.0 mm bubbles arranged in bands.
17-17.5	A well defined line of large bubbles, sometimes enlarging into cavities which can be penetrated with a knife blade. This is probably an old autumn surface.
17.5-25	Fairly clear ice with some 1.0-2.0 mm bubbles in faint bands.
25-31	Ice like that above, but the top centimeter is recognizable as soaked firn. Possible autumn surface at the base of this layer.
31-38	Firn, with thin ice layers at the top and a 3 cm ice layer in the center.
38-45	Fairly clear ice, with 1.0 to 1.5 mm bubbles and occasional faint banding. Possible autumn surface at the base of this stratum.
45-50	Loosely bonded firn. Grain size 1-2 mm. Stratum has a well marked upper limit, but grades downwards into ice.
50-70	(base of pit) Blue ice (bluer than in pits above here), with a slight increase in the number and decrease in the size of bubbles at 66.5.

5. (Three-quarters of the way from S8 to F2B) (345 m)

cm	
0-23	Ice. At 5.5 a well marked bubble horizon. Below 14-15 cm bubbles increase in number and decrease in size.
23-27	Firn, with a well marked upper limit.
27-33	Ice. At its base a firn stratum, usually thin, but sometimes reaching up almost to 27.
33-51	(base of pit). Ice. Essentially blue, but whiter, faintly banded strata with small bubbles at 33-39 and 45-51.

6. (F2B) (343 m)

Solid blue ice, but a slightly more bubbly stratum 12-15 cm below the surface.

LOCATION F2B ELEVATION 343 m

Stratigraphy (pit dug 6 August 1958. Observer Hollin)

cm	
0-40	1958 snow
40-46	White with large bubbles. An intermittent possible surface at 46.
46-58	Blue, with an intermittent possible surface at 58
58-63	White, with small bubbles. Sharp and continuous break at 63.
63-75	Large bubbles, possibly refrozen slush.
75-78	Blue, with a well marked and continuous line of large bubbles at 78.
84, 86	Lines of large bubbles
89-93	White, with small bubbles: a continuous layer.
93-104	Blue, with some crystal boundary bubbles at the top. At 104 a well marked and continuous break with large cavities.
114	A well marked break, beneath a blue layer with small bubbles at its base.
124, 129	Lines of large bubbles

The horizons at 63, 78, 93, 104 (?) and 114 appeared to be autumn surfaces.

LOCATION B6 ELEVATION 322 m

Stratigraphy (Pit dug 14 August 1958. Observer Hollin)

cm	
0-25	1958 snow, which included a steeply sloping crust. Very hard at the base.
25-30	Blue-white ice with large bubbles, all above a line of cavities
30-45	Blue
45-50	As for 25-30
50-110	Homogeneously blue with large bubbles

Discussion

No convincing interpretation possible. It was noted that the ice surface below the 1958 snow here was formed by small crystals, less than 5 mm across, which probably represent the "Is" of Section VI-B-4.

LOCATION B7 ELEVATION 302 m

Stratigraphy (Pit dug 8 August 1958. Observer Hollin)

cm	
0-18	1958 snow. Below 18 is ice.
18-31	Distinctively white, with small bubbles. Split evenly into three layers by lines of bubbles. Top layer has at its base cavities filled with hoar crystals. Hexagonal figures abundant at 31, but decrease steadily up to 18.
31-38	Large bubbles.
38-47,	
47-59,	
59-74	The following sequence is repeated three times, starting from 38 downwards: (a) Clear ice with few hexagonal figures. (b) Crystal boundary bubbles. (c) Hexagonal figures more plentiful. (d) Many small to large bubbles.
100	The sequence above begins again, but fades out downwards into homogeneous ice.

Strata not easily differentiated. Stratigraphy was first observed on the walls of a vertical crack, then followed round the rest of the pit.

Discussion

Possible autumn horizons at 38, 47, 59, 74 cms. It is difficult to suggest a sequence of events that would produce the stratification between 18 and 38 cms. Note, however, that after some compaction this interval might show a stratification resembling that of the three sequences below it.

LOCATION B8 ELEVATION 281 m

Stratigraphy (Pit dug 14 August 1958. Observer Hollin)

cm	
0-20	1958 snow. No hoar at base. Below 20 is ice.
20-36	White with large bubbles, but includes some bluish layers. A very well marked base, with crystal boundary bubbles below.
36-42	Blue, bubble free.
42-44	White, large crystal boundary bubbles. What appears to be a continuous surface in the center.
44-53	Blue, but with a white, large bubble layer of varying of varying thickness in the center (46-49 on east wall).

53-65	White; crystal boundary bubbles in the upper part and medium sized ordinary bubbles in the lower. Between them, at 58, the straightest, most continuous and most distinctive horizon in the pit.
65-74	Blue.
74-78	Small bubbles, with a well marked line of hoar filled cavities at the base.
78-110	No clear stratigraphy.

The horizons at 58 and below dip inland a few degrees.

Discussion

The ice surface below 20 could be the result of ablation. Possible autumn horizons at 43, 58, 78 cms.

Photograph of pit: Fig. 47 (p. 251)

LOCATION S-1 (B9) ELEVATION 262 m

Observations here were made in a pit some 20 meters to the north of S-1 and on cores drilled from a hole some 30 meters to the north.

Stratigraphy (Pit dug 5 July 1958. Observer Hollin)

cm	
0-13	1958 snow. Coarse grains and intermittent crust just above the ice below.
13-25	White ice. Very large bubbles (many more than 1 cm long), particularly in the upper 3 cm. The density of this upper ice was 0.76 ± 0.02.
25-43	Blue. Large bubbles concentrated in layers at 27.5, 31.5, 34, 37.5, and 40, giving the impression of blue between. The layer at 31.5 lies above what may be an old autumn surface.
43	A well marked line, which may be an old autumn surface. The air in bubbles just above here could have originated from low density, porous ice below, subsequently filled in by melt water.
43-65	White. Upper third slightly blue. Middle third fractures into small pieces. Lower third fractures into pieces up to 7 cms long.
65	A distinct break from big bubbles above to small below.
65-84	Blue. An essentially homogeneous stratum with small, irregularly shaped bubbles. Bluest in the upper part and slightly layered in the lower.
84-104	Very blue and particularly bubble free in the lower part. Otherwise plentiful hexagonal figures and discoid rather than spherical bubbles, concentrated in layers layers at 87, 89, 95, and 100.
104-113	Whiter. Larger bubbles particularly plentiful at the top.
113-200	Blue. Plentiful hexagonal figures and bubbles (mostly discoid) up to 9 mm diameter, all concentrated in layers at 123-4, 129-32, 136-9, 155-63, and 171-87. These layers show as whiter parts of the pit wall. The interval 163-171 is relatively bubble free, and the intervals 139-155 and 187-200 even more so.

Discussion

The ice just below 13 cm is probably refrozen slush from the late summer. Its large cavities will probably be filled from above by melt water of later summers. Possible autumn surfaces occur at 31.5 and 43 cm. On 5 July an inspection was made of the ice which had originated in the summer as pools of water round the legs of the S-1 instrument shelter. This ice was quite bubbly and was very rich in hexagonal figures.

Immediately above it was a thin layer of ice, with obviously small crystals, which was probably the metamorphosed remnant of early autumn snow. No dirt was seen in this pit.

Bubble and crystal observations

These observations were made on ice extracted from a hole drilled between 14 and 24 June. This was the first hole drilled into ice by the 1958 team, and considerable difficulty was experienced with blunt cutting edges on the drill. Eventually it proved necessary to rebuild (by welding) and resharpen the cutting edges after each 10 or 20 meters of drilling. The help of Chief Griffith, U.S.N., in this connection is gratefully acknowledged. Perhaps as a result of the abundant bubbles and hexagonal figures in the ice, few cores of any length were extracted from this particular hole, and most of the recovered material was shattered.

a. Bubbles and hexagonal figures

The ice from S-1 resembled that from other parts of the superimposed ice zone in that its bubbliness varied considerably from layer to layer. At one extreme the ice could be so bubbly that it had the low density of 0.76 quoted above, and at the other it could be almost bubble free. (Other density determinations on S-1 ice gave 0.87 ± 0.02 for some moderately bubbly ice from 11 m and 0.90 ± 0.02 for ice from 10 m below the surface.) Observations were made at the following approximate depths (cm).

100	Hexagonal figures usually 1-3 mm in diameter. Figures possibly more rounded (less sharply hexagonal) in the upper part of the core.
300	Many hexagonal figures 5 mm across. The appearance of many figures is suggestive of migration along a thermal gradient, as described by Nakaya.
320	Many hexagonal figures not as thin as usual. Many subspherical bubbles with one flat face.
450	Milky bands approximately 3 cm wide (probably the effect of coring) contained in one case layers 3-4 mm apart of very fine bubbles, just visible under an 8x lens.
1100	Common large bubbles have a diameter of 4 mm. Many bubbles with one flat face. These faces have widely varying orientations, presumably corresponding to the orientation of the containing or bounding crystals. Large hexagonal figures.

b. Crystal size

In a block cut near the surface crystals appeared to be the same size in both the clear and the bubbly ice, perhaps a little smaller in the latter. Crystal areas were measured in four slides cut from random depths between 0 and 11 meters, with the following results:

Slide	Average area	Remarks
1	135 mm^2	Moderately bubbly. Common large crystals 2 cm across
2	540	A few small bubbles. One crystal more than 6 cm long
3	109	Quite bubbly. Common large crystals 2 cm across
4	150	Almost clear. Crystals up to 5 cm long

c. Crystal fabric

Because the cores recovered from this hole were so short, and the crystal size relatively large, it was not possible to find more than 46 distinct crystals in the longest available piece of core. The c-axes of these 46 (from 683-698 cm) have been plotted in Fig. 35. At other depths (0-150 cm and 1030-1130 cm) axes have been measured from several core lengths of unknown relative azimuth. For these two depths, therefore, only the vertical angles of the axes can be compared, and these have been plotted in Fig. 34. In that figure each column represents the percentage of axes per unit of area in each 10° interval. (A random distribution of axes would include 11.4 times as many between 80 and 90° polar as between 0 and 10° polar.) The conclusions that can be drawn from Figs. 35 and 34 are limited, but any preferred orientation present must be very weak, and in fact it seems likely that the fabric at S-1 is essentially random.

LOCATION B10 ELEVATION 245 m

Stratigraphy (Pit dug 26 July 1958. Observer Hollin)

Depths below are below the ice surface. Above this surface was 35 cm of 1958 snow, harder towards its base.

cm	(West wall of pit)
0-20	White, fractures coarsely. Bluer layers (larger crystals?) at 5-6 and 9-12.
20-25	Blue and very clear.
25-33	White. A possible autumn surface at 28.
33-37	Blue.
37-42	White.
42-47	Blue.
47-49	White (small crystals?). A possible surface.
49-100	Blue and fairly homogeneous. A little bubblier at 70, 86 and 106. What lineations there are appear horizontal.

	(East wall)
0-28	Bluer than west wall, but fairly homogeneous.
28-35	White.
35-50	Horizon 49 on the west wall can be traced round.
53-55	Blue.
65	A distinctive layer of small bubbles.
103	Some very large bubbles (1-2 cm long)

Discussion

Seen from a distance, the east wall (Fig. 48) shows five distinct sequences of white-blue in 100 cm. Superficially this suggested an annual accumulation of 20 cm of ice. But on 28 August the pit was revisited in order to obtain a block of ice for crystal studies. The north and south walls of the pit were reexamined and the following most probable autumn horizons identified:

cm	(Below ice surface)
15	White (large bubbles) at the top. A very level horizon at the base.
29	Level horizon in the center of a bubbly zone.
41	Below small bubbles and above large.
50	A zone of crystal boundary bubbles.
62	Small bubbles at the base.
72	A very level horizon, with large bubbles below.
82	As for 72.

Assuming that there were no erosion surfaces in the pit this implies an accumulation of only 12 cm.

Bubbles

Crystal boundary bubbles were common, at the edges of apparently regular polygonal crystals. These bubbles were typically 1.5 mm in diameter, 10 mm long, and quite straight. The larger hexagonal figures were usually 1 mm in diameter. Some larger bubbles were 4 mm in diameter and 20 mm long.

Crystal Size

Average cross sectional areas from five plates, cut for fabric study from the upper 50 cm of the pit:

Plate (photo No.)	No. of crystals	Average area (mm^2)
78	45	190
79	42	230
80	90	70
81	17	650
82	17	580
83	20	340

Crystal Fabric: Fig. 36 (p. 248)

LOCATION 406 ELEVATION 220 m

Stratigraphy (Pit dug 12 July 1958. Observers Hollin, Cronk)

cm	(East wall of pit)
0-18	White (coarse), but bluish in middle
18-24	Bluer; appears to grade into strata above and below.
24-28	White, coarse.
28-33	Blue, graded as for 18-24.
33-41	White. Possibly large crystals.
41-51	Less white. Possibly small crystals. Grades into stratum below.
51-130	Blue, with many hexagonal figures. Essentially homogeneous, but white zones at 64-67 and 83-92.

cm	(SE corner of pit; NE corner is similar)
0-5	White (coarse), grading into stratum below.
5-13	Blue.
13-21	White, coarser downwards.
21-27	Blue.
27-30	White, coarse. A well defined horizon below.
30-34	Blue, but with no well defined base. This stratum merges into a white one on the south wall. Sloping horizons here suggest either slush flow or the soaking of sastrugi.
34-46	White, coarse. Possibly large crystals.
46-53	White, but not so coarse. Possibly small crystals.
53-62	Almost blue. Possibly very large crystals.
62-98	Blue, with increasingly frequent layers of small bubbles. 67-70 Bubble horizon 92-98 Concentration of dirt specks. Corresponds to 83-92 on east wall. Many bubbles and hexagonal figures, which seem to have a preferred dip inland.

cm	(West wall of pit)
0-20	Essentially blue, but large bubbles and intergranular cavities near the surface and at 17-18 cm give a white appearance to those areas. The upper 5 cm of the SE corner gradually thin out and are blue here. Suggests ablation or a locally wetter area.
20-40	Generally white. The most prominent stratum in the pit. At its top the best defined horizon in the pit, between a blue layer above and a coarser white one with hoar crystals in intergranular cracks below.
40-58	Possibly large crystals at the top. Bluer and clearer downwards.
58-60	Many spherical bubbles.

60-69 Clear blue.
69-72 Many spherical bubbles.
72-88 Clear blue.
88-96 and especially 92. Bubbles, hexagonal figures, dirt specks.
96-130 Blue. Regular and continuous bubble bands at 107 and 119-122. Bubbles are commonly 3 mm in diameter.

Discussion

This pit obviously represents several years of superimposed ice accumulation, with the horizon at 92 cm representing a summer when dust was blown uphill onto the ice sheet. However, it is not clear from the stratigraphy or fabric whether this ice has accumulated locally or is superimposed ice from further uphill, not buried deeply, and being exhumed now by ablation.

Crystallography

A vertical section 35 cm long from the ice at 1 m showed no stratification by crystal size. Many crystals were over 10 cm long. A fabric study from horizontal sections here is shown in Fig. 37.(p. 248).

LOCATION B12 ELEVATION 198 m

This area appears to be in a relative hollow between 406 and B13, and to have relatively more accumulation than other parts of the trail.

Stratigraphy (Pit dug 26 July 1958. Observer Hollin)

cm	
0-30	1958 snow. Ice below.
30-33	A typical surface white zone, very bubbly.
33-36	Bluer.
36-39	Whiter. Possibly autumn surface at base.
39-42	Bluer.
42-46	Whiter.
46-51	Bluer. Possible autumn surface at base.
51-100	(approx.) Homogeneous ice with lines of large bubbles (superimposed type ice rather than firn type ice) dipping approximately 55° E. A preferred orientation of bubbles and hexagonal figures was found occasionally below 45 cm. A blue band 15 mm wide, with a line of bubbles in the center, dips approximately 45° E and fades out upwards at approximately 50 cm. Possibly a shear plane but unlikely.

Discussion

The ice below 51 appears to be glacial. That between 30 and 51 may be the same ice disturbed by melting during the previous summer or summers. More probably it represents one or two three seasons of superimposed ice formation on top of the previously ablated glacial ice.

LOCATION B13 ELEVATION 175 m

Stratigraphy (Pit dug 5 July 1958. Observer Hollin)

cm	
0-12	White, with big bubbles.
12-22	Bluer. Concentrated at the top were many small specks of dirt. These were often inside bubbles (at their bases) but they did not show signs of having melted their way downwards. At the base of this layer were spherical bubbles.
22-31	Whiter, apparently with larger crystals at the top.
31-41	Bluer, with bubbles decreasing downwards.
41-46	White, with distinctively small bubbles.

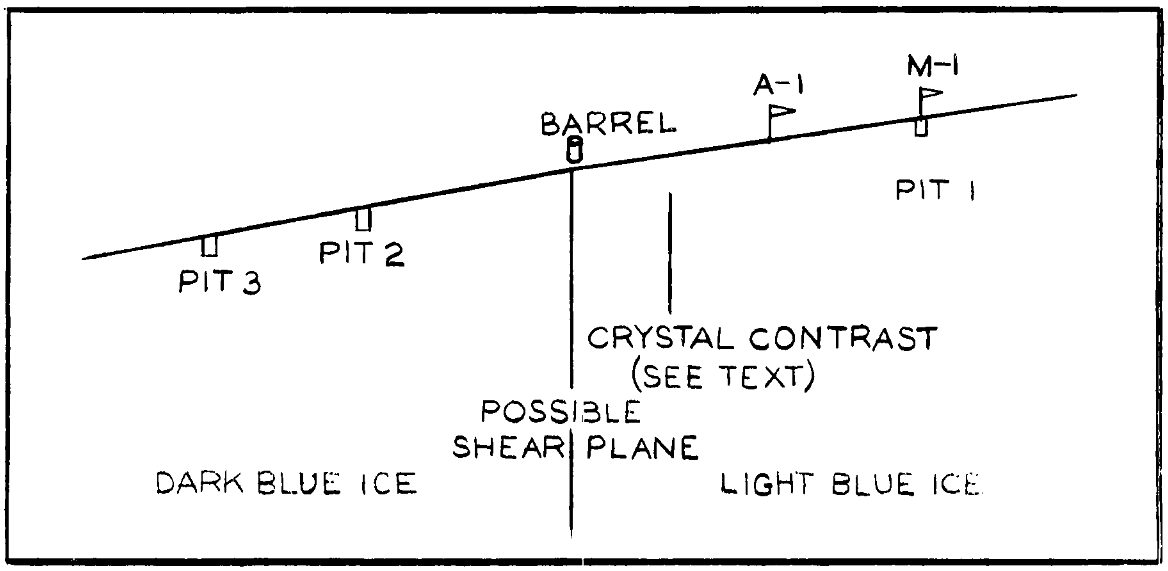
46-50	Blue, with large bubbles.
50-54	Whiter.
54-59	Bluer.
59-64	White, with a distinctive layer of large bubbles at the base.
64-86	A moderate quantity of bubbles. Some at the top are up to 2 cm long (they do not appear to have been produced by the melting down of cryoconite) but those at the base are spherical. There are distinctive layers of large bubbles at 83 and 86.

Discussion

Between 403 and C1 (see Figs. 11 and 14), and for a few hundred meters north and south of the trail, there is a pronounced upward bulge in the ice sheet (see also Section VI-B-4). B13 lies on the inland half of the bulge, where the general angle of the ice sheet is less than usual. Melt streams which would otherwise cross this area are diverted round the bulge. It appears from the stratigraphy that this area consequently forms an enclave of superimposed ice in the middle of what is otherwise an ablation zone. As ablated ice from B12 moves into the area of the bulge it probably acquires a covering of several years of superimposed ice, illustrated by the stratigraphy of this pit. Eventually, on the very crest of the bulge, deflation and sublimation probably become greater than accumulation, and ablation once more becomes predominant. The dirt below 12 cm is almost certainly of immediately local origin since no more than occasional specks of dirt were ever observed further uphill than this.

LOCATION A1 ELEVATION 170 m

Fig. 31 (see also Figs. 11 and 14)
Location of three pits dug on 25 July 1958 (Observer Hollin)



PIT 1

No clear stratification. A melt-disturbed zone (for a discussion of melt-distrubed zones see Section VII-A-10, at the top; apparently large crystals (> 5 cm across common) at 60 cm; and very blue ice with superimposed ice type bubbles at 90 cm.

PIT 2

This pit was dug in a faint snow covered depression which may have been an old stream bed. The following strata were encountered, starting from the surface:

1. Small crystals, probably late summer snow turned directly into ice (see Section VI-B-4.

2. Coarse, bubbly ice with plentiful specks of dirt.

3. A cavity 2-3 cm deep, filled with hoar.

4. Clear, glassy ice, sometimes bubbly at the top, and with plentiful dirt.

5. White ice. Some of the bubbles include at their bases dirt which has left bubble trails above (see Section VII-A-8).

The melt-disturbed zone in this pit is 20 cm deep. Below this are evenly distributed bubbles, generally spherical, not all the same size, and probably larger than the bubbles at S-2. Dirt is common throughout the pit, but cannot be definitely distinguished as sheared dirt or cryoconite.

PIT 3

cm	
0-25	Melt disturbed zone. Crystals at the top appear small. Dirt occurs only at the top of the pit, as in 2(5) above.
25-90	Homogeneous ice, with bubbles that are generally spherical but unequal in size.

Discussion

This appears to be a region of net ablation, where old superimposed ice or Mile 10 type ice is being exhumed. It was noticed on 19 November 1958 that there was a marked break in crystal size 5 m downslope from A1 (see Fig. 31). The surface uphill had many crystals more than 10 cm across, and the surface downhill had small crystals less than 1 cm across. This break or the color break 5 m further downhill (see Fig. 31) may represent the lower limit of superimposed ice formation in 1957-58, or may mark the upper limit of significantly deformed ice form the shearing zone at the base of the glacier.

LOCATION C1 ELEVATION 161 m

Pit dug 19 July 1958 (Observers Hollin and Robertson)

This pit was dug approximately 5 m west and 15 m south of C1, on the line of the highest of the three shear planes marked in Figs. 11 and 14. This area is in the zone of summer melt streams. The melt-disturbed layer in the pit reached 85 cm in the shear plane (see below), but was normally only 5 or 10 cm thick. Below this the ice was homogeneously blue, although some parts of it, in no discernible pattern, had less bubbles than others. The main feature of the pit was the shear plane which crossed its north and south walls. The shear plane averaged 3 to 4 cm in width, had a generally vertical dip, but in one part actually dipped to the west - that is it overhung. Since it carried dirt, this shear plane was presumably nearly parallel to the ice bed at one stage, but the movement of the surrounding ice has rotated it now to a vertical position.

Samples of ice from this pit were examined in the laboratory. The fabric of the homogeneous ice on either side of the shear plane is illustrated in Fig. 38. It should be remembered that the ice plates from which this fabric was obtained were horizontal, but that any foliation in the ice was probably approximately vertical. Other ice plates were cut which crossed the shear plane. The ice in it was breccia like and shattered easily. The margins of the 4 cm wide shear zone included small bubbles elongated in the direction of shear. The center of the zone was bubble free. The plates were examined under crossed polaroids. Crystals were typically 7 to 8 mm long, were elongated in the direction of shear, and nearly all extinguished together. Crystallographically, the shear plane appeared to be a zone rather than a line, in that no continuous line of crystal boundaries could be traced in the center of the plane.

LOCATION M3 ELEVATION 157 m

Observer Hollin

On 19 August 1958, a hole was drilled just below and to the north of M3, 7-8 m uphill from the shear plane which marks the striking transition from dark blue ice to grey ice (see Figs. 11 and 14). Cores from this hole were examined both in the field and the laboratory, with the results below. All dirt inclusions were noted, but air inclusions were examined only at random intervals.

cm	
180	A few small but distinctive hexagonal figures, extremely thin, in the usual clusters. Many figures had the doughnut form suggestive of migration along a thermal gradient. The orientation of these figures varied somewhat, so that the crystal orientation here was perhaps not so strongly preferred as at 700 cm (see Fig. 39). Up to half of the usual sub-spherical air bubbles at this 180 cm level had one flat face, frequently sub-hexagonal in plan.
337	Clusters of hexagonal figures.
610-640	Many relatively small crystals, less than 1 cm long. Many bubbles elongated to 5 mm or even 1 cm. No hexagonal figures seen.
665-668	A dirt filled shear zone. Most of the dirt was extremely fine, but macroscopic specks were scattered at random throughout the zone. Crystallographically the zone was less than 2 cm wide and consisted of small crystals, many less than 1 mm across. Bubbles in the zone were sparse and randomly distributed.
800	Another dirt zone, which disintegrated while coring was taking place. Bubbles from the dirt zone appeared to be 1 mm across as compared with 2 mm on either side of the zone.
800-880	Sporadic dirt specks.
880-980	Ice disintegrated easily.
970-980	No hexagonal figures visible. Smaller bubbles.
990	A wedge shaped granitic pebble 2-1/2- cm long. (This obstructed the drill and had to be pounded loose with an ice chisel mounted on drill extension rods.) A shear zone.
1100	Dip of foliation 25-30°.

Fabric (Fig. 39)

The average crystal cross sectional area on one plate of this study was 33 mm^2. Some crystals were noticeably larger than others, and these have been marked in the fabric diagram. It was noticed that adjacent (but not the same) crystals often shared almost the same orientation.

Observations by Cronk (10 March 1958)

The main shear plane here was examined at the surface, where it forms the boundary between the two colors of ice. It dipped inland at 30° and contained fine dirt and a few pebbles, and the ice immediately below the shear plane was quite clear. More detail on this area is included in Section III-F.

LOCATION M4 ELEVATION 148 m

Observer Hollin

Cores to a depth of 355 cm were taken here in the winter of 1958, and examined in the laboratory with the following results:

cm	
0-55	1958 snow.
105-150	Homogeneously bubbly. Most bubbles were small and sub-spherical (~1 mm diameter), but there were also many discoid bubbles, hexagonal figures and doughnut shaped figures.
275	Randomly distributed dirt.
345	Dirt. The biggest piece was a rock chip 5 mm across.
355	Dirt. Good hexagonal figures.

Fabric: Fig. 40

Discussion

Hexagonal figures seem to be continuous throughout the core. Together with the small bubbles they imply an origin for this ice somewhere in the region of Mile 15. However, the small bubbles may also be a result of the metamorphism suggested by the fabric diagrams, and at this stage the origin of the ice cannot be stated with any certainty. The average cross sectional area of the crystals observed here appeared, by eye, to be the same as that at M3 (33 mm^2).

LOCATION Between Upper Base and C2 ELEVATION 137 m

Observer Hollin

Immediately below the main shear moraine large lee drifts of hard snow formed during the winter of 1958. Some 20 m downhill from the moraine these drifts were 1 m thick and had a density of 0.48. Some 40 m downhill, below the thickest drifts and at a point where the surface was locally bare ice, a core was taken during the winter. The whole of this core appeared to consist of superimposed ice formed below the moraine, in that it contained irregularly sized and shaped bubbles, hexagonal figures throughout its length, and scattered dirt arranged in apparently horizontal layers. A length of core from 250 cm was examined more closely in the laboratory. It had a dense bubble structure (similar to that of the ice at the Lower Grinnell location), many very small hexagonal figures, no dirt, and crystals which with one exception were much less than 1 cm long. The estimated crystal cross-sectional area in the fabric plate was 50 mm^2. The weakly oriented fabric (Fig. 41) supports the conclusion that this ice was superimposed rather than glacial. It is probable that this area just below the moraine forms a small zone of alternating accumulation and ablation.

LOCATION Isolated Moraine (J) ELEVATION 125 m

1. Pit at Stake D. (27 August 1958.
   Observers Hollin, Cronk)

Thirty-five cm of 1958 snow, above ice. At 20 cm, ice layers totalling 1 cm in thickness, with pellets and harder snow below. Intermittent depth hoar above both the main ice surface and the ice layer. The ice layer was probably produced by the rain storm of 17 May.

2. Pit on the shear plane
   (15 August 1958. Observer Hollin)

This pit was dug 5 m north of the boulders of Isolated Moraine. These boulders were sharply angular and appeared to have emerged or been uncovered only recently, in that many of them were precariously balanced and were covered with particles of boulder clay not yet weathered off. The pit, elongated in an E-W direction, was planned to cut across the shear planes presumably associated with the boulders. The following stratigraphy was observed:

cm	
0-50	1958 snow.
50-75	Disturbed by surface melting. Included an old stream bed, cryoconite, depth hoar, superimposed ice, disturbed ice, and horizontal layers of dirt.
75-150	Ice with small bubbles, many elongated vertically to 2 cm. The pit cut a well defined, dirt-filled shear plane, striking 025° and dipping in general vertically. In some places the line of the shear appeared to form a small crack.

The floor of this pit was levelled and smoothed so as to provide a horizontal section of the shear plane and the surrounding ice. Descriptions of the ice were recorded, starting at 0 cm, at the east end of the floor, and ending at 110 cm, at the west end. Mostly horizontal sections of ice were also cut from the pit floor (parallel with it) and examined in the laboratory. The results of these investigations were as follows:

cm	
0-30	Dirt and relatively few bubbles.
10-20	Crystals at least 5 cm long. The edge of the biggest was marked by a row of bubbles. No clear preferred orientation.
30-32	The main dirt-filled zone, usually 2 cm wide. The dirt was not continuous, but occurred in randomly distributed clusters of relatively coarse material. The largest single pebble was oriented parallel with the shear plane. Both the shear plane and the ice for

several cm on either side had a relatively small bubble content, presumably the result of a sorting within the ice or of the upwards escape of air through cracks to the surface. In the shear plane itself there was a possible crack in the center and there were a few bubbles. For some 5 cm on either side of the plane small bubbles elongated in the direction of the plane were arranged in rows parallel to it. The elongation and the rows persisted still further away, but the bubbles became larger. In the area of the shear plane many crystals were more than 6 or 7 cm long, and sections cut in two planes (axes) showed that the crystals had a disc or slab like shape. No fabric studies were made, but the crystals appeared to have a preferred orientation. Away from the shear plane crystal lengths decreased to 2 or 3 cm. Two or three crystals abutted against lines of bubbles, but there appeared to be no continuous line of crystal boundaries in the shear plane.

32-62 The generally dark brown color of the ice in the shear plane grades into white.

50 Quite bubbly ice. Crystals have a cross sectional area much less than 100 mm^2, are elongated, and have a preferred orientation.

62-74 Grey ice.

74-85 White ice.

75 Quite bubbly, with bubbles elongated and arranged in lines sub-parallel to the shear plane. Crystal areas roughly 100 mm^2, with no clear preferred orientation.

85-110 Grey and white bands, becoming steadily darker and leading to a line of sporadic dirt.

90 A shear plane which had not been noticed in the pit was discovered in the laboratory. Crystals on either side of the plane were larger (several cm long). The plane had three parts, in horizontal sections. The eastern part consisted of a fairly well defined, 1 cm wide band of 2 mm long crystals. The center of the plane consisted of a thin line of small crystals, many less than 1 mm long. The western part consisted of a fairly well defined, 1.5 cm wide band of 7-8 mm long crystals. All the crystals in the shear plane and surrounding ice were elongated and had a strongly preferred orientation.

Discussion

Obviously this ice had moved up from the basal part of the ice sheet. It contained some disc shaped bubbles but no hexagonal figures. The most noteworthy feature of the pit was the association of the most obvious shear plane with very large crystals. The lines of bubbles in this plane resemble those in other shear planes, but the crystal boundaries cut across them. It seems likely that this is an old shear plane in which many small, similarly oriented crystals have joined together following a relaxation of stress. The shear plane at 90 probably represents a contemporary line of deformation. Perhaps the most obvious shear plane has become too choked with dirt to permit further movement.

LOCATION The Ramp Observer Hollin

The foundation of the Ramp is provided by the glacial ice of the continental ice sheet, and it is in this ice that shearing has taken place and the shear moraine has formed. But, as the Ramp has developed, melted snow and ice have been distributed over its surface as superimposed ice, so that in the lower part of the Ramp the old glacial ice is covered now and invisible. As will be seen in the succeeding pages, the lowest parts of the Ramp; e.g., the Grinnell "Glacier", appear to consist wholly of superimposed ice, which has grown outwards as isostatic uplift has removed the ablating effect of the sea.

The following observations were made on the Ramp east of Clark Island:

28 August 1958	A weasel journey on the 100 m contour showed a patchwork of superimposed and sheared glacial ice.
6 January 1959	A 275 cm core taken 200 m above the base of the Ramp profile (see Section II-B-9) appeared to be all superimposed ice.

Note that some of the ice in rock encircled hollows below the Ramp may in its lower part be glacial ice that has remained undisturbed at negative temperatures for several thousand years since the retreat of the ice sheet. This applies only to hollows well above 30 m elevation, since all snow and ice drifts below that must post-date the 30 m postglacial emergence of the land from the sea.

LOCATION Middle Grinnell ELEVATION 36 m

Observer Hollin

These observations were made a short distance downhill from Stake 3 of Movement survey III-G (see Fig. 11).

1. Observations in a pit dug on 7 August 1958

cm	
0-10	1958 snow. Medium.
10-35	1958 snow. Soft.
35-50	1958 snow. Hard.
50-54	1958 snow. Soft. Traces of depth hoar.
54-58	Intermittent ice laminae, with interfingered depth hoar (weakly developed). The laminae are probably wind or melt crusts similar to those observed at S-1.
58-63	Relatively clear ice, probably the refrozen last slush flow of summer. Large bubbles (many 1 cm across), with the biggest concentrated at the top of the layer (which has some large cavities at the top). This layer was carefully checked for signs of hexagonal figures, but none was found. Perhaps an early snow cover protected the ice against late summer radiation.
63-85	A distinctive layer of white ice, broken by a rather clear zone between 65 and 68. Some of the air included in this white zone may have been flushed out of the cavities in the layer below, which had probably included many cryoconite and inter-crystalline bubbles.
85-90	A clear zone, with bubbles of various sizes. Grades into the zone above.
90-95	Nearly all the cryoconite in the pit was found in this layer. The cryoconite was at the bottom of bubble trails and cavities which reached to 63.
95-140	Apparently homogeneous ice, with small bubbles and a greenish color. A few faint clear layers.

2. Observations on a core drilled to 1150 cm on 6 August 1958

These observations show quite clearly that the ice here is superimposed. Cores from approximately every meter were examined in the laboratory. They included both clear and bubbly layers, dipping between 0° (horizontal) and 15°. The layers followed no discernible sequence. Bubbles included large cavities (10 mm x 10 mm x 30 mm) at 430 cm, large and medium spherical bubbles throughout the whole length, and "finger" and "vertical" bubbles (see Section VII-A-7) in the lower five meters. Hexagonal figures occurred throughout the whole length, but were less than 1 mm across in the lower half. Dirt conformed to the general bedding. Dirt particles were commonly arranged in vertical rows, suggestive of cryoconite shafts. The narrower shafts are filled now by single ice crystals, up to 2 cm tall. The dirt itself often occurs in pellets which, when melted out, are springy, elastic to the touch, and suggestive more of cryoconite than basal debris. Strikingly similar crystal fabrics from 4 and 11 meters depth are illustrated in Figs. 42 and 43.

Since the present sea cliff of the Grinnell Glacier is approximately 15 m high, and since the land here has recently been uplifted 30 m, it is probable that the ice here has arrived in its present location since the uplift. As to its actual origin there are three possibilities: (a) that it emerged from the interior of the ice sheet, above the shear moraine, as part of a glacial re-advance; (b) that it originated below the shear moraine, but some distance above where it is now; and (c) that it has accumulated locally. Against (a), the relatively abundant dirt in the ice suggests that it was formed below the shear moraine--a conclusion supported by the relatively high conductivity of the ice (see Section VII-A-11). Against (b) is the evidence of little or no movement provided by Movement survey III-G. Possibility (c) therefore seems the most likely. Finally, one outstanding puzzle in this location is the origin of the greenish tinge in the ice at 95-140 cm. This was the only location in which this was observed.

LOCATION Lower Grinnell ELEVATION ~26 m

Observer Hollin

These observations were made approximately halfway between Middle Grinnell and the Grinnell Glacier sea-cliff, just above the crevasses behind the cliff.

1. Observations in a pit

cm	
0-24	White ice, slightly blue at the top.
24-32	Blue ice.
32-42	White ice.
42-50	Blue ice and a layer of what appeared to be cryoconite.
50-75	A sequence of blue, white, blue ice.
75	A sharp change to brownish ice, with small bubbles. The top 40 cm were disturbed.

The floor of the pit was split by two N-S cracks, probably crevasses.

2. Observations on a core drilled to 377 cm on 5 August 1958, a short distance away from the pit

cm	
0-65	1958 snow, with crusts at the base. Ice below, apparently uncrevassed.
65-75	Various bubble patterns. No hexagonal figures. (cf. Middle Grinnell). Dirt and an old cryoconite shaft.
130	A speck of dirt, and large bubbles as at S-1.
170	A milky zone, with some large bubbles as at S-1, and innumerable small bubbles less than 1 mm across. Some bubbles disc-shaped, but no convincing hexagonal figures.
174-199	Alternate clear and white bands. The clear bands have crystals 3-4 mm across. Some bubbles are 4-5 mm across and suggestive of superimposed ice. Also present are hundreds or thousands (in each slide made) of very small bubbles (approximately 0.2 mm across), which from a distance leave the ice looking clear. The white bands have crystals 1-2 mm across and include many small firn like (S-2 type) bubbles, which seem to have a preferred elongation.
300-327	A "wirewool" type of bubble structure.
337-377	Fig. 44 shows the result of a fabric study at this depth. The largely random fabric supports the idea that this is superimposed ice formed below the shear moraine.

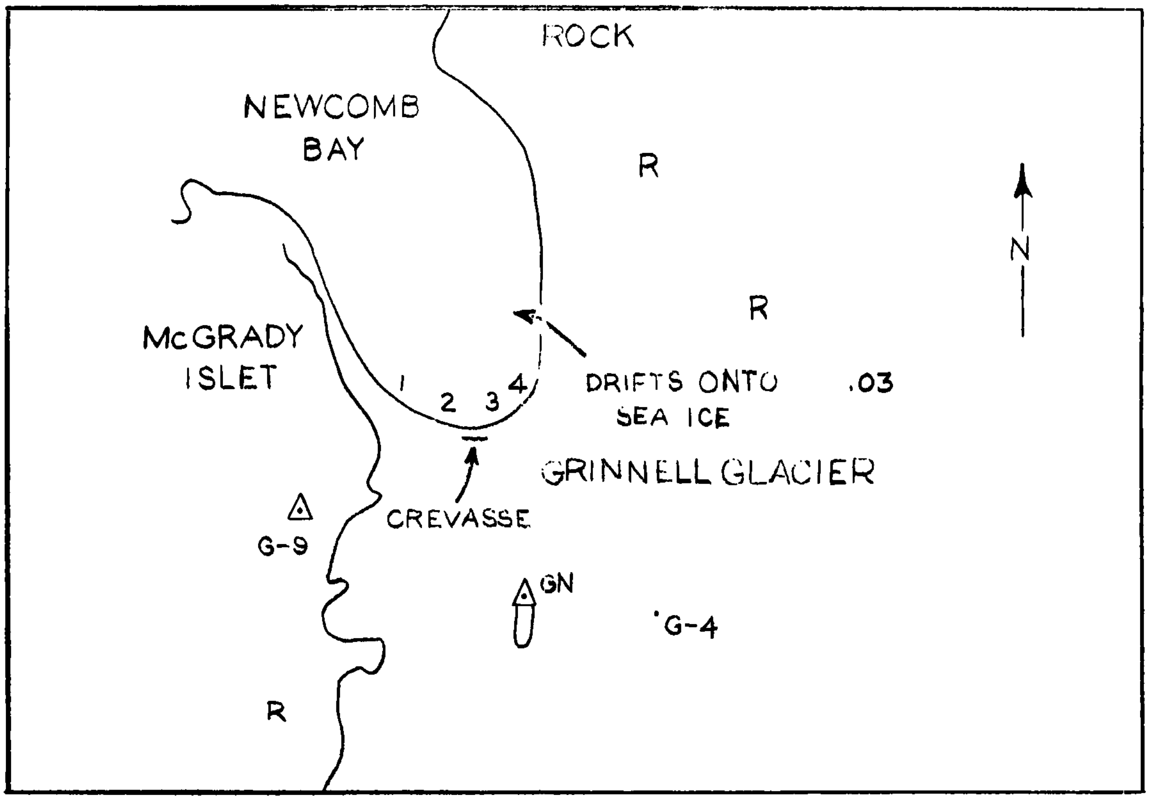
<u>LOCATION</u> Crevasse immediately behind sea cliff of Grinnell Glacier

A vertical section of the ice here was examined to a depth of 12 m in a crevasse. The ice consisted of approximately horizontal, alternating clear and very bubbly layers. Many of the bubbles were of the "finger" type (see Section VII-A-7). No convincing hexagonal figures were seen. Dirt was generally associated with the bubbly layers.

<u>LOCATION</u> Front of the Grinnell Glacier sea cliff

Marine soundings in this location are shown on H.O. Chart 6656, and imply that the cliff is aground. The cliff was visited on 21 August 1958 via the sea-ice, and samples (1, 2, 3, 4) were collected from the cliff at points shown approximately on the sketch map below (from Fig. 11).

Fig. 32 Location of samples on Grinnell Glacier sea cliff



Viewed from the sea-ice the cliff shows several horizontal bands of dirt, but it was impossible to decide whether these were sedimentary or metamorphic (e.g., in shear planes). The upper part of the cliff did appear at one place to be sliding over the lower part, but certainly no large debris was being carried by the cliff. Sample one included bubbles that appeared to be elongated. Sample two had elongated bubbles, but had irregularly shaped crystals 1 cm across, with no clear orientation. Sample three had large crystals, one 4 cm across, and Sample four had variously sized crystals up to 1 cm across. Hexagonal figures were observed in the cliff face but may have been formed locally. No hexagonal figures (or dirt) were seen in the samples. The high conductivity of the samples (see Section VII-A-11) suggests that this ice also has been formed locally.

LOCATION Ice cliff between Mitchell Island and Robinson Ridge ELEVATION 3 m

Report by Hollin

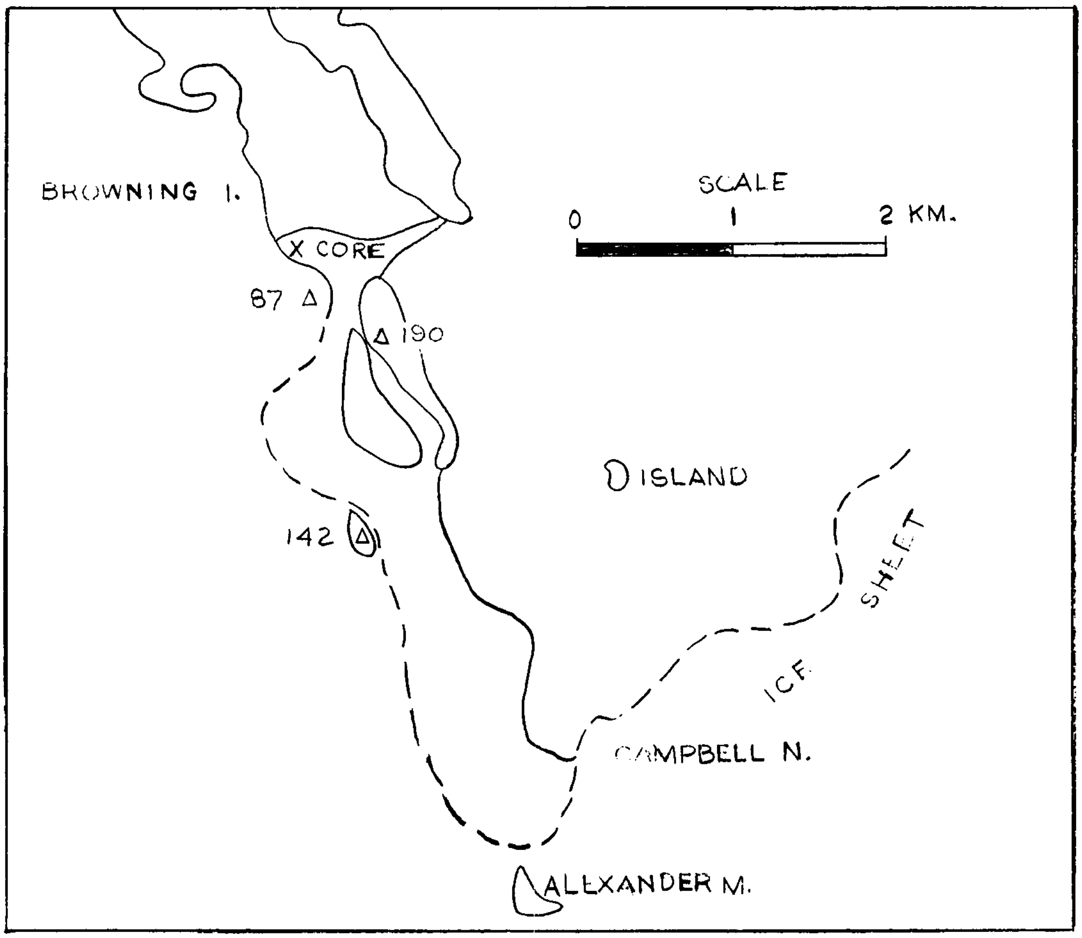
Between Mitchell Island and Robinson Ridge there is a break in the shear moraine, and the ice sheet reaches the sea directly in the form of an ice cliff. For some distance inland of the cliff there are narrow crevasses. The ice cliff is banded horizontally. This ice cliff was visited in December, 1958, via the sea ice and a block was cut from its base, above the winter snowdrift. It was thought at the time that this block was actually part of the original ice sheet, but subsequent inspection of color photographs of the cliff suggests that the block may merely have been a superimposed product of melted and refrozen winter snowdrifts. This conclusion is supported by the relatively high conductivity of the ice (see Section VII-A-11) and the largely random fabric (Fig. 45). A feature of this fabric is the shortage of low equatorial angles. This cannot be traced to experimental error. The ice contained a dense network of small spherical and elongated bubbles without any sign of a preferred orientation. These bubbles had a common diameter of 0.8 mm. The elongated ones were up to 3.00 mm long and were often bent. No hexagonal figures were seen, perhaps because this cliff is not oriented towards the highest sun. The average cross sectional area of 474 crystals in Plate 77 was 14 mm^2.

LOCATION Southeast of Browning Island

Observers Hollin, Robertson (21 December 1958)

An ice formation with the properties of both sea ice and an ice shelf was discovered on the western side of the bay southeast of Browning Island. Its extent is indicated by the diagonal hatching on the map below. Tide cracks separate it from the mainland and the ice sheet.

Fig. 33 Southeast of Browning Island



This formation may be a relict from the ice sheet or an old ice shelf, or it may represent merely the addition of several years' snowfall to an original layer of sea ice. The latter seems the most likely possibility, but in any case the original foundations of the formation may well have disappeared in a cycle of surface accumulation and bottom melting. It is doubtful if the formation is anyshere thick enough to experience significant plastic deformation. In favorable lights it has a blue color quite different from the green of the surrounding sea ice. The existence of this formation is clearly favored by three factors: 1. Its sheltered position relative to the wind, which normally sweeps the fast ice out to sea each summer; 2. the considerable accumulation it receives as a result of (1); and 3. the protection which the bay must afford against vigorous marine calving and melting.

The formation is broken by tide cracks into sections of different heights above sea level. The highest section, which has a small cliff at its northern end, where it joins the sea ice, occurs north of Pt. 87 (see map). This section was drilled on 21 December 1958, and the following stratigraphy recorded:

cm	
0-30	Coarse and moist (effect of the current summer).
30-300	Homogeneous snow, grain size less than 0.5 mm. This was clearly 1958 snow, and the large amount of it must have been a result of the lee situation in an area of otherwise strong and persistent winds.
300-450	A mixture of coarse firn and ice pellets. Grain size variable. The cores were moist at 425, and water ran out of them at 450 cm.
450-550	Practically homogeneous ice, but original features such as ice layers and a uniform grain size of 2-3 mm could still be distinguished.
550-650	Increasingly slushy, and tasted of salt. Drilling was stopped here because the drill began to jam.

Density, temperature and conductivity equipment was not available on this particular occasion, and only limited conclusions can be drawn from the above data. However, it is possible to make a rough estimate of the thickness of the formation as follows:

1. The presence of active tide cracks at the inland margin of the formation implies that it was afloat. (The cracks were typically wide and ragged edged, quite unlike the strand cracks of the Maudheim ice shelf, for example. Presumably, therefore, they penetrate the formation, and this fact alone sets an upper limit to its thickness.) By eye the elevation of the snow surface above sea level was estimated to be three meters. However, a float lowered after the drilling was completed settled at 410 cm, and this seems the most likely elevation.

2. The mean density of the firn above 410 cm is likely to have been within 0.05 of 0.45 gm/cm^3.

3. So much brine ran out of the cores below 550 cm that it seems possible that brine had almost completely replaced air in the firn below sea level. Presumably as firn is pushed below sea level by fresh accumulation it no longer undergoes densification but instead has its interstices filled by brine circulating within the formation. The density of a mixture of firn (0.45), brine (1.02) and no air would be 0.97.

4. The total thickness of the formation works out, from the above, to be 41 m.

Against the above result it is difficult to imagine such a great thickness of brine soaked firn remaining coherent under the influence of even the slightest current. No coherent cores could be recovered below 550 cm in the drill hole. Note therefore that if the density of 0.97 in (3) above were in fact only 0.55 then the calculated thickness of the formation would reduce to only 7 (just below the limit of drilling) instead of 41 meters. It is very likely that some such lower density applies, and that in fact some air is after all retained by the submerged firn.

The above conclusion is supported by thermal considerations:

1. Average air temperatures above the formation are of the order of: midwinter -20°C, midsummer 0°C, and annual -8°C. Since NaCl can remain in solution at -22°C the circulation of brine inside the formation appears to be feasible. However, the rapidity with which brine filled up the drill hole does argue for a temperature at sea level not so far below the freezing point, and this strengths the view that 7 rather than 41 meters represents a likely thickness for this formation.

2. Note also that if brine does circulate inside the formation then it doubtless accomplishes some melting while doing so, and that this would very definitely tend to destroy the cohesion which a thick formation would require.

In view of the limited amount of data available, further speculation concerning this particular formation is unlikely to be profitable. Somewhat similar phenomena have been investigated by Vickers (1958, Little America) and Stuart and Heine (1959, McMurdo Sound) and are described in this series of reports. More detailed studies of this type of formation would be worthwhile for various reasons; for example, the problem of just how thick sea ice can become is of considerable interest and is relevant to traditional speculations concerning the origin of the Ross and other ice shelves.

Additional notes

1. A firnberg or iceberg which looked as though it might have come from the formation was observed at the entrance to the large bay on the north side of Browning Island.

2. On the eastern side of Boffa Islet a steep snow or ice bank terminated on the seaward side in a cliff several meters high (photographed), much higher than a normal ice foot. The upper slope of the bank had the appearance of having graded at some time into the upper surface of a formation similar to that described above. Presumably the formation has subsequently melted or floated away. (Note however that the existence of wave washed slabs up to 30 m or more on Pts. 190 and 142 argues against the recent existence of a fully-fledged ice shelf in this area.)

LOCATION Haupt Nunatak area

Report by Hollin

It could be seen from Ardery and Holl Islands that the ice sheet south of Robinson Ridge had much more relief than that to the north. Although in general it retained the parabolic profile typical of an ice sheet margin the surface of this southern area was broken into a series of shallow domes and basins. As late as November, 1958, it was noticed that these domes consisted largely of blue ice, which had presumably received no net accumulation during the winter. Further south still, in the basin of the Vanderford Glacier, accumulation in general seemed to be small, probably as a result of the more persistent katabatic winds in that area (see Section VI-A-3-b). This part of the ice sheet was occasionally crossed en route from Wilkes Station to Haupt Nunatak and Browning Island, and halts were made at the following points during November and December, 1958. (Elevations are by altimetry and approximate.)

1. At 520 m (see Fig. 1)

   Fresh powder snow on bare ice.

2. At 232 m, 4.8 km NE of Haupt Nunatak (see Fig. 10)

A large area of bare ice. The surface had small bubbles and small crystals a few mm across, and appeared to be superimposed.

3. At 198 m, between (2) and Haupt Nunatak, 4.0 km from the latter

Ice from 20 cm included a few hexagonal figures and small bubbles with a possibly preferred orientation. Possibly ablated ice.

4. At 156 m, between (3) and Haupt Nunatak, 3.1 km from the latter

Ice from 20 cm included a few hexagonal figures and many small, spherical bubbles. This pit was dug on 23 December 1958, and melting had already begun to dissociate the surface ice crystals. They were not interlocking. The pit was at approximately the upper limit of old stream channels.

5. Rocks, between (4) and Haupt Nunatak, 2.6 km from the latter (see Fig. 10)

A short line of erratics here probably represents the beginnings of a moraine inland from Haupt Nunatak, analogous to the shear moraine further north. Little fine-grain rock material was seen here, and it may have been buried following a few years of net accumulation in this immediate area. (Operations Highjump and Windmill photographs show much more rock and moraine exposed in the southern Windmill Islands than was visible in 1958.) Further information concerning the rocks in this location is included in the section on Glacial geology.

6. At 153 m, 3.2 km SE of Haupt Nunatak (see Fig. 10)

The surface ice included only a few hexagonal figures, and in general appeared to be ablated. The results from pits 2, 3, 4, and 6 show that the ablation zone in this area has an upper limit of at least 156 m. The ice at pits (2) and (3) may well be superimposed, but it may be noted that stronger winds and less accumulation in this area will cause both the upper and lower boundaries of the superimposed ice zone to be higher here than they are on the S-2 trail. The existence of an ablation zone here, where rock exposures are few, suggests that the ablation zone on the S-2 trail is not merely a result of the heating effect of the local rocks.

7. Rocks, between (6) and Haupt Nunatak

These few erratics are described in the section on glacial geology. A line of occasional boulders connects them with the erratics at (5), but the origin of the two groups is probably different.

8. At 61 m, immediately NNW of Haupt Nunatak

Summer stream channels for approximately 1 km NNW of the nunatak contain erratic boulders and gravel in their beds. No excavations were made in this area but it seems likely that this material represents melting out basal moraine.

9. The area between Haupt Nunatak and Browning Island

The persistence of this large area (approximately 5 x 11 km) of apparently grounded but essentially level ice poses several interesting problems. For example, if this ice has always been aground then in order for it to have advanced to Browning Island it must have been (assuming a basal shear stress of 0.7 bars) approximately 400 m thick at Haupt Nunatak. This implies that, while 400 m of ice have been ablated from Haupt Nunatak and considerable post-glacial weathering has taken place there, the ice just SE of Browning Island has not thinned or retreated at all. Possibly the ice there is supplied from the Vanderford Glacier, or possibly the ice in this area was originally afloat and has only recently been grounded by the general isostatic rebound. These and other possibilities will be discussed in the report on Glacial geology.

LOCATION The Vanderford Glacier ELEVATION 45 m

Report by Hollin

A full analysis of the movement data (Movement surveys III-A and B) from this glacier has yet to be made. The wave crests observed appeared to move at approximately the same speed as the glacier as a whole. A search of the literature concerning such waves has not yet been made, but they may be analogous to the ice shelf "hinge line valleys" described by Robin (1958). Because the surface of the glacier in the area of the survey was essentially level rather than convex it seems probable that the glacier there was afloat. Ice from the glacier surface was examined, and contained strongly oriented elongated bubbles. This implies that the area must be an ablation zone. Against this, however, is the fact that because of its high speed it would seem difficult for the glacier to have spent enough time in the ablation zone to have exposed such oriented ice. On the other hand, it may be noted (1) that these samples were taken from the edge of the glacier, where movement is less and (2) that drainage in the abundant crevasses of the glacier must discourage the development of a superimposed ice zone between the firn and ablation zones. Future workers might profitably collect a few blocks of this ice for fabric study.

LOCATION Cape Folger and nearby ELEVATION 0-25 m

Report by Hollin

These observations were made on 26 August 1958, in the course of a mission to install on Cape Folger the two beacons described in Section III-C. The Cape was reached by vehicle over the sea ice, which was slightly pressured in front of the Cape and split by cracks radiating from it. The ice which forms the Cape is probably aground. The Cape was climbed by ladder and its upper surface found to be heavily crevassed, as is much of the coast hereabouts, seen from above by helicopter in January, 1959. On the August mission observations were also made south of Cape Folger at other points at the edge of the ice sheet. All these observations are grouped below by location.

1. On top of Cape Folger, at the first beacon

An ice sample 90 cm below the surface had small bubbles and large hexagonal figures, with no apparent preferred orientation. This was probably superimposed ice, which may of course have been old and ablating superimposed ice.

2. The ice cliff at Cape Folger

Viewed from a distance this approximately 15 m cliff appeared whitest at the top. A block was cut from its base at an elevation of approximately 3 m. Its conductivity was relatively low. The bubbles in this block were concentrated in undulating layers, but the block included no completely clear bands. Bubbles included many small spherical types, but the majority were highly elongated in approximately the direction of flow, mostly to 5 or 10 mm but many to more than 10 mm and some to 60 mm. Many discoid bubbles were noticed, elongated in the direction of flow, and groups of hexagonal figures were visible through a 3.5x lens. Ice plates cut for a fabric study of this block were horizontal but did not show the elongation of the bubbles, which were presumably in the dipping part of an undulation at this point. This dipping in the foliation is probably reflected in the fabric (Fig. 46). The average cross-sectional area of 154 crystals in Plate 75 was 48 mm^2. If hexagonal figures are indicative of radiation melting then this ice was presumably first formed no higher than 1000 m above sea level.

3. Three stops below the ice cliff southwest of Cape Folger, heading towards the Windmill Islands

a. Ice at the first stop was the clearest seen during 1958. No banding was visible. The ice contained mostly spherical (some with one side flat) bubbles very regularly and sparsely distributed. No plates were cut, but under crossed polaroids one piece of ice appeared to have a strongly preferred crystal orientation. One crystal was more than 10 cm long. The low air content and the composition of this ice suggest that it is recrystallized ice which originated either in the lower part of the firn zone or in the superimposed ice zone.

b. Ice from this stop contained well defined clear bands roughly 3 cm thick. The intervening bubble bands contained large, geometrically perfect hexagonal figures, and "finger" bubbles arranged in parallel layers. Some bubbles had the form of an extremely fine network ("wirewool" bubbles) with a faint vertical lineation.

c. Further to the south the ice cliff included clearly visible crevasses sealed by refrozen water. The cliff section included one or two continuous bands of firn, distinctively white, which could be penetrated by a knife. The ice of the cliff had a low air content, and under crossed polaroids showed no preferred crystal orientation.

Discussion

The observations on this mission to Cape Folger are particularly interesting because they were made in an area which climatically is much more typical of the East Antarctic coastline than is the area of the Windmill Islands, with their low albedo. Of most interest is the question whether the ice sheet in this area is still accumulating and being limited only by the calving of icebergs, or whether the ice sheet is significantly ablated by sublimation and melting before it ever reaches the sea. In support of the first alternative is the evidence of accumulation in the form of superimposed ice on top of Cape Folger and the firn bands at location (3-c). However, stronger evidence supports the second alternative and leads to the conclusion that the superimposed ice and firn bands above are not accumulating in situ but are being exhumed by ablation following burial. The stronger evidence is twofold. Firstly, the ice on top of Cape Folger was practically snowfree when visited in August, so that the annual accumulation is extremely unlikely to exceed the tens of centimeters of summer ablation which may be expected here. Secondly, the deformed ice at Cape Folger and location (3-a), though it might conceivably be the product of shearing as the ice moves over rock just out of sight below the sea ice, is more likely to be the product of prolonged flow at considerable depth.

Ideally an Antarctic coastal ice cliff would contain at the top ice formed locally and at the base ice formed in the center of continent. But at location (3-c) the whole of the visible part of the ice cliff appears to have been formed only as far inland as a point where climatic conditions are similar to those at Mile 10 on the S-2 trail. Almost certainly the lower part of the ideal section is missing in this area, and it is reasonable to assume that ice from the center of the continent flowing towards the Windmill Islands is channelled either into the Vanderford and other glaciers to the southwest or towards Cape Poinsett and the area to the north. The ice that emerges at the main shear moraine probably does not originate more than a few score kilometers to the east and southeast. Perhaps this accounts for the absence in the Windmill Islands of any of the post-Cambrian erratics commonly found at other points on the coast east of Antarctica.

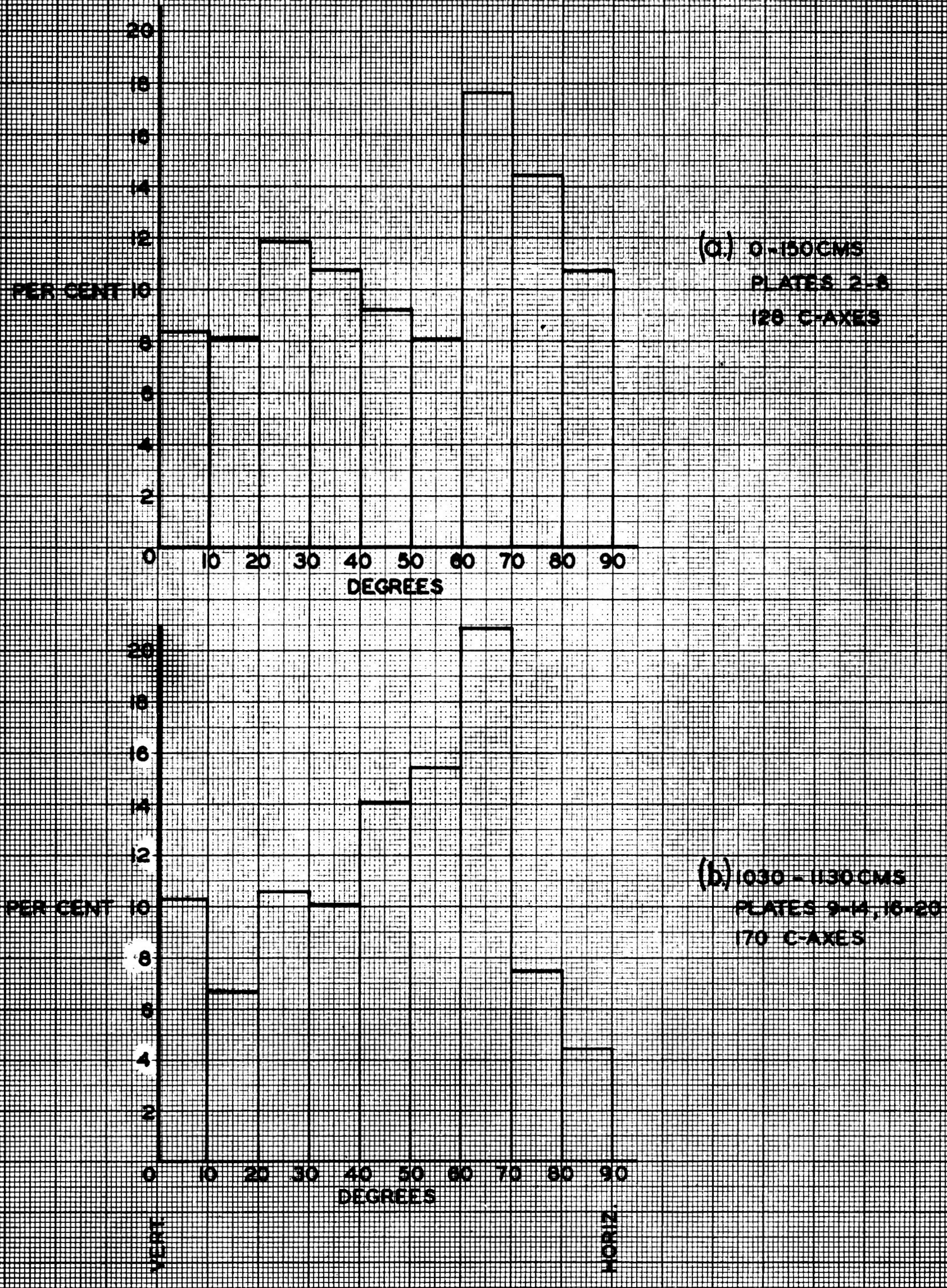


FIG. 34
S-1
PERCENTAGE FREQUENCY OF POLAR ANGLES

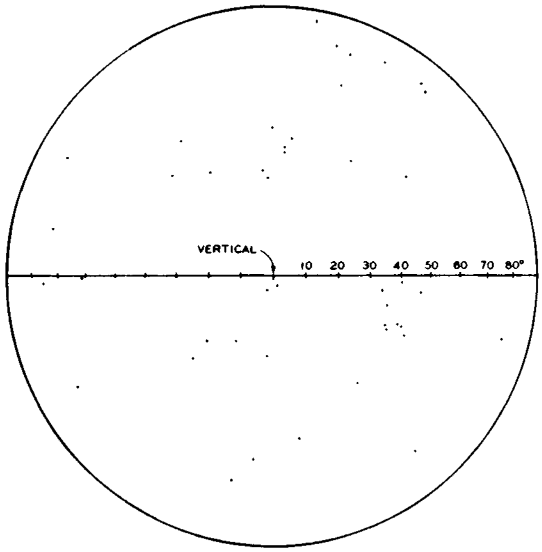


FIG. 35
S-1 (683-698 CMS)
PLATES 54-59
46 C-AXES

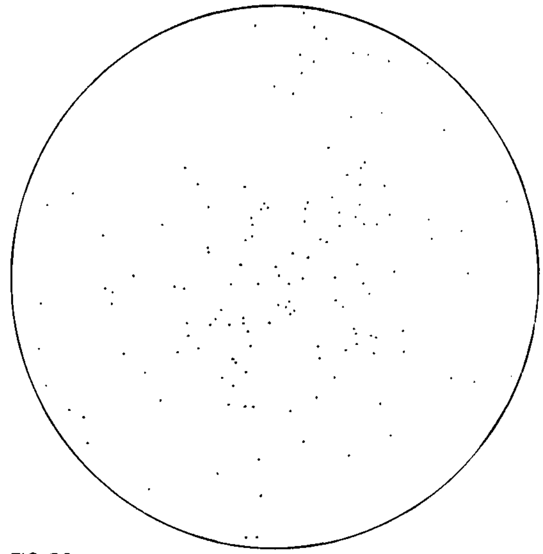


FIG 36
B 10 (UPPER 50 CMS)
PLATES 78-83
150 C-AXES

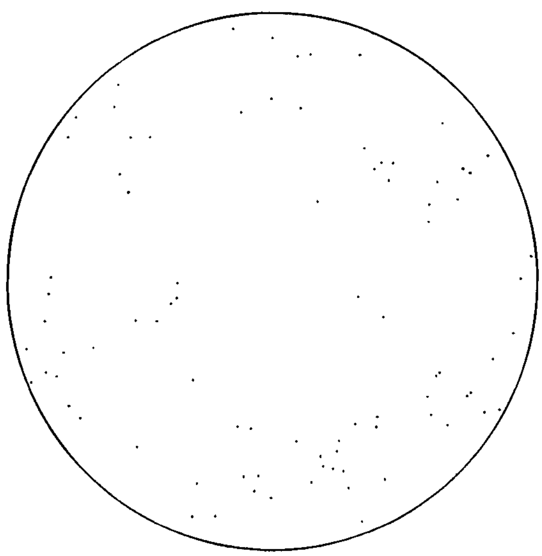


FIG. 37
406 (80-100 CMS)
PLATES 21-24
84 C-AXES

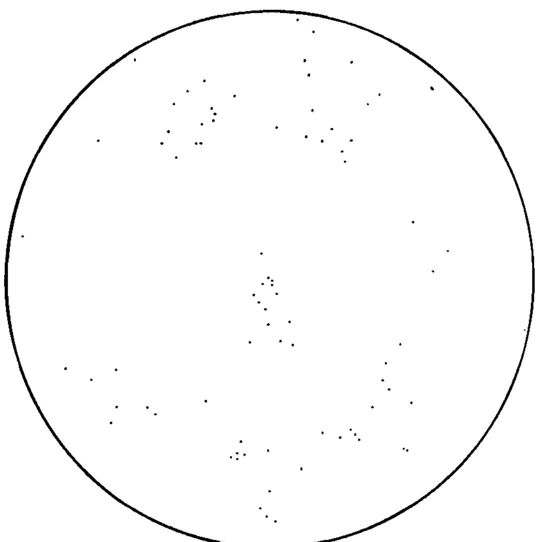


FIG. 38
C1 (100 CMS)
PLATES 26-37
88 C-AXES

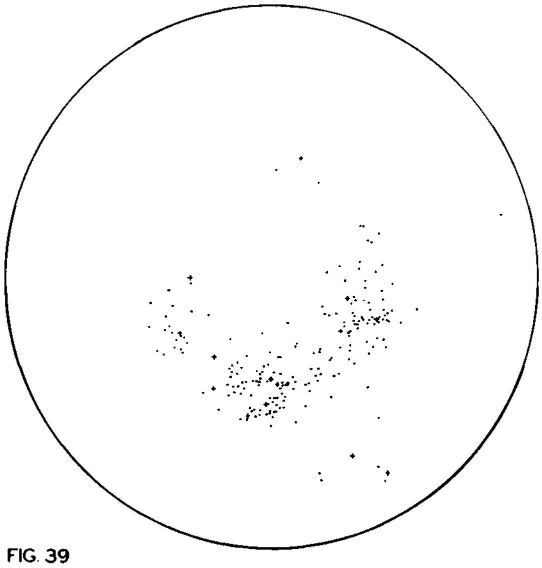


FIG. 39
M3
PLATES 66 (710 CMS), 67 (714), 68 (718), 69 (726), 70 (730)
205 C-AXES + = LARGE CRYSTALS

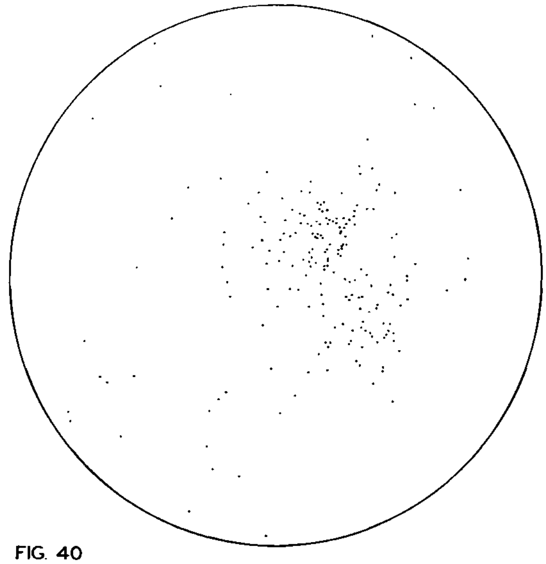


FIG. 40
M4
PLATES 63 (225 CMS), 64 (229), 65 (233)
196 C-AXES

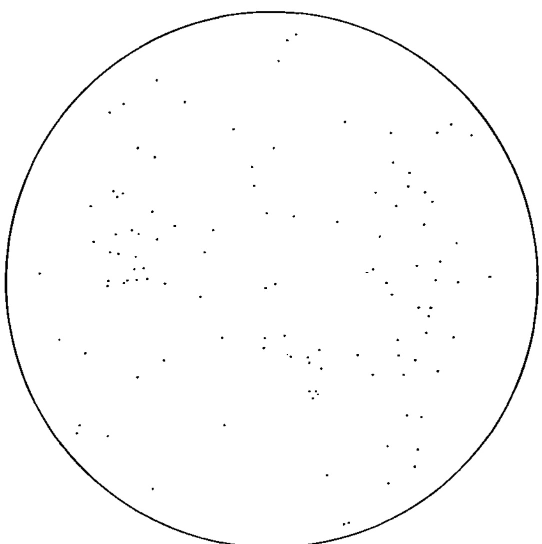


FIG. 41
C2-UPPER BASE
PLATES 60 (300 CMS), 61 (304), 62 (308)
112 C-AXES

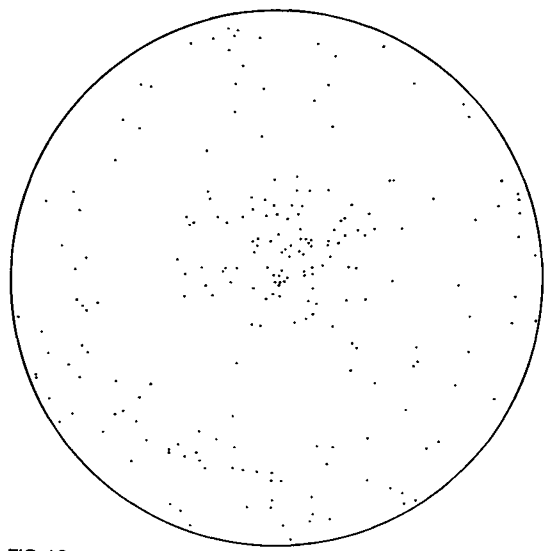


FIG. 42
MIDDLE GRINNELL
PLATES 44 (386 CMS), 45 (390), 46 (394), 47 (398), 48 (406)
224 C-AXES

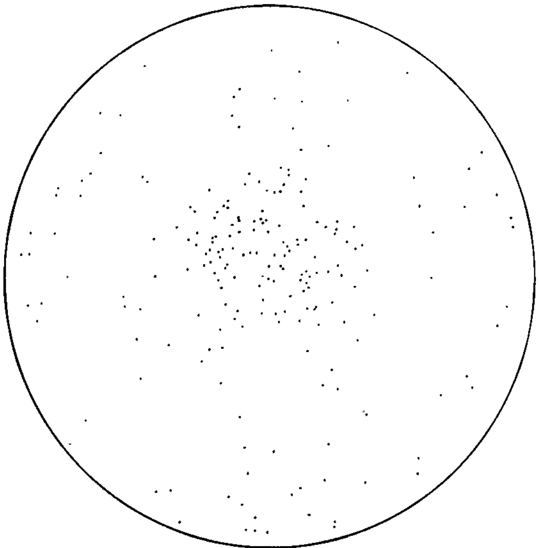


FIG. 43
MIDDLE GRINNELL
PLATES 50(1127 CMS), 51(1131), 52 (1139), 53(1147)
210 C-AXES

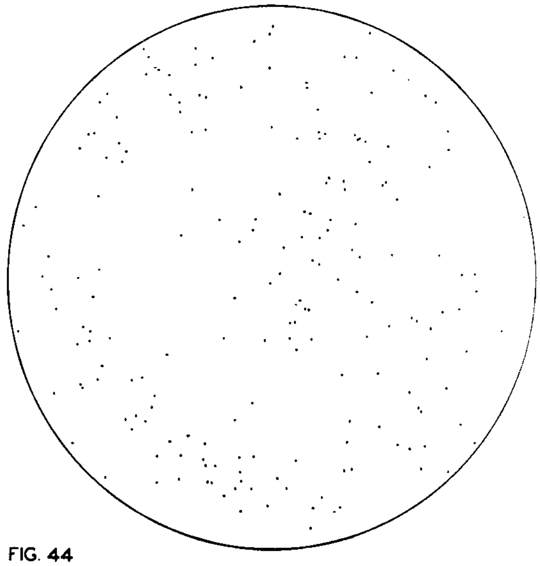


FIG. 44
LOWER GRINNELL
PLATES 38 (337 CMS), 39(344), 40(351), 41(358), 42(372), 43(377)
198 C-AXES

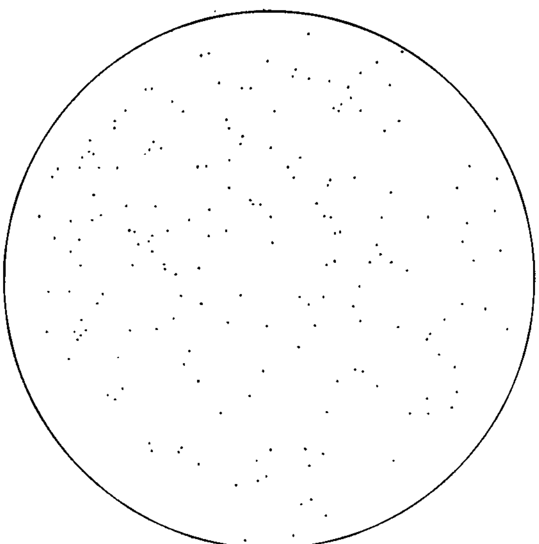


FIG. 45
MITCHELL-ROBINSON SEA CLIFF
PLATES 76,77
196 C-AXES

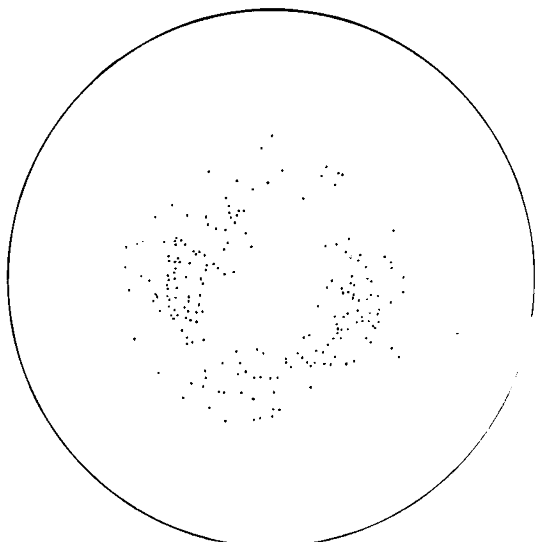


FIG. 46
CAPE FOLGER
PLATES 71-75
205 C-AXES

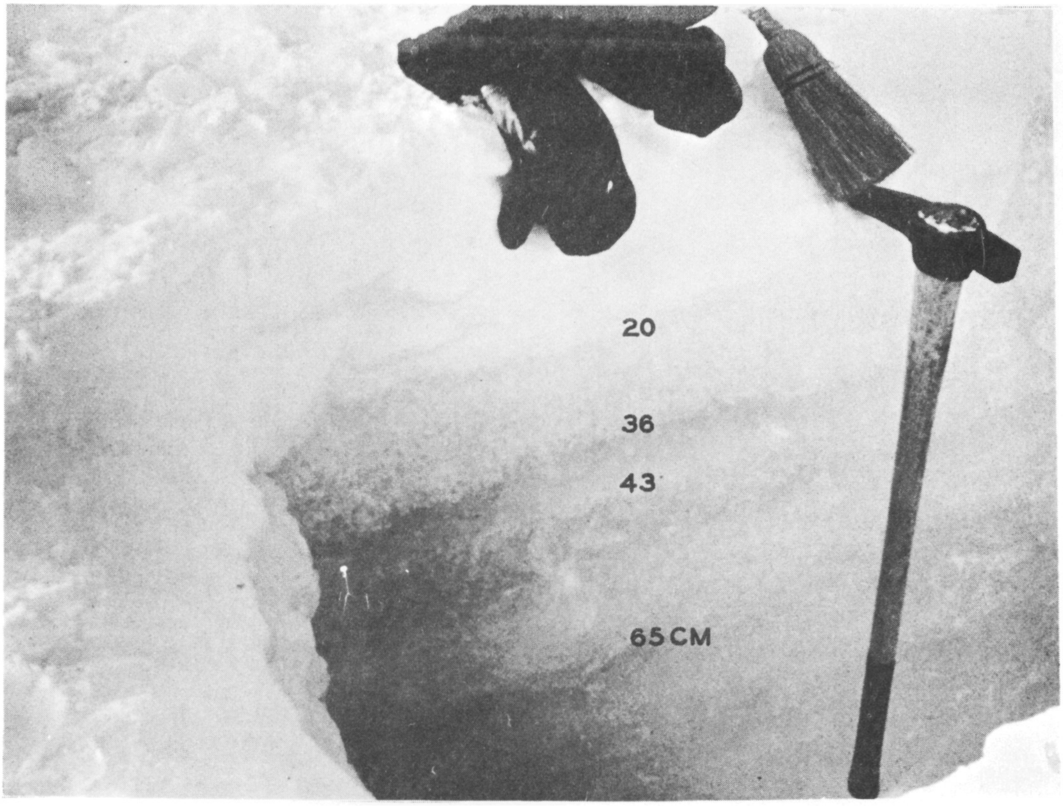


Fig. 47. Pit at B8. Superimposed ice stratigraphy. Whisk broom and Steuri type pick. Photograph by J. Hollin.

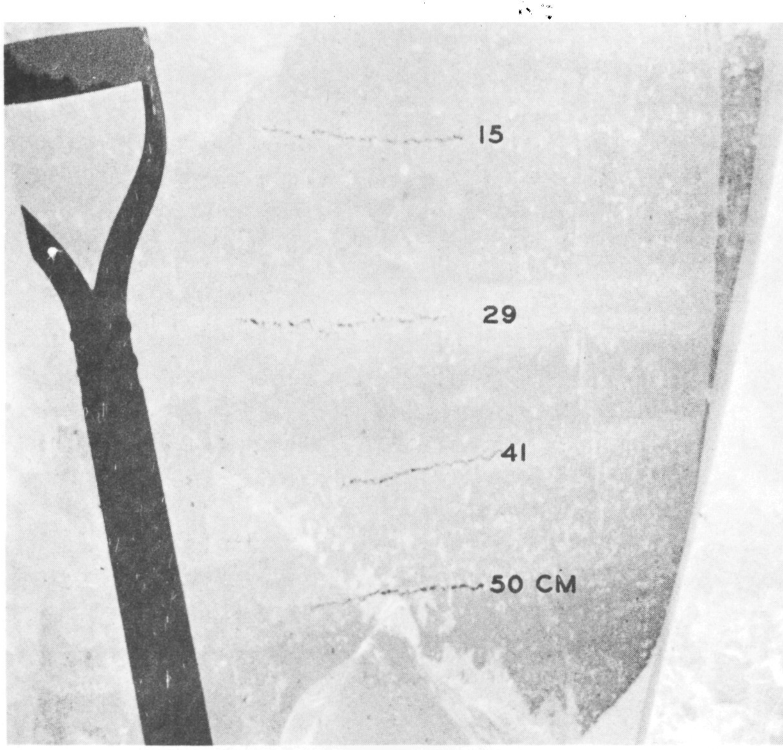


Fig. 48. Pit at B10. Superimposed ice stratigraphy. Photograph by J. Hollin.

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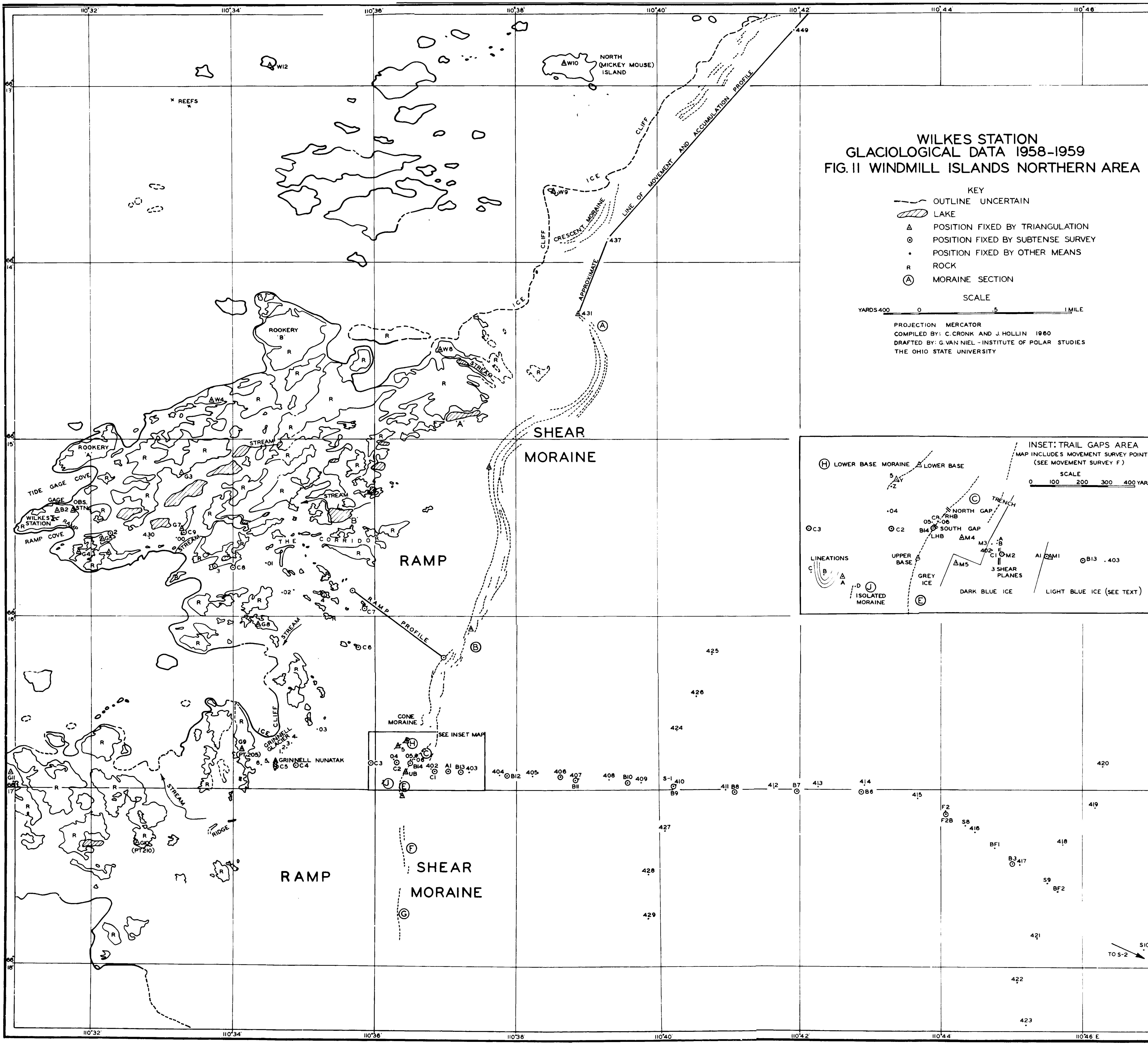
RF 825-2, Part X
Fig. 11. Windmill Islands
Northern Area


WILKES STATION
GLACIOLOGICAL DATA 1958-1959
FIG. 11 WINDMILL ISLANDS NORTHERN AREA
KEY
OUTLINE UNCERTAIN
LAKE
POSITION FIXED BY TRIANGULATION
POSITION FIXED BY SUBTENSE SURVEY
POSITION FIXED BY OTHER MEANS
R ROCK
(A) MORAINE SECTION
SCALE
YARDS 400 0 .5 1 MILE
PROJECTION MERCATOR
COMPILED BY: C. CRONK AND J. HOLLIN 1960
DRAFTED BY: G. VAN NIEL - INSTITUTE OF POLAR STUDIES
THE OHIO STATE UNIVERSITY
INSET: TRAIL GAPS AREA
MAP INCLUDES MOVEMENT SURVEY POINTS
(SEE MOVEMENT SURVEY F)
SCALE
0 100 200 300 400 YARDS
LOWER BASE MORAINE
LOWER BASE
NORTH GAP
SOUTH GAP
TRENCH
LINEATIONS
UPPER BASE
GREY ICE
ISOLATED MORAINE
3 SHEAR PLANES
DARK BLUE ICE
LIGHT BLUE ICE (SEE TEXT)
NORTH (MICKEY MOUSE) ISLAND
REEFS
ROOKERY 'B'
ROOKERY 'A'
TIDE GAGE COVE
WILKES STATION
RAMP COVE
THE CORRIDOR
RAMP
SHEAR MORAINE
CRESCENT MORAINE
ICE CLIFF
LINE OF MOVEMENT AND ACCUMULATION PROFILE
APPROXIMATE
RAMP PROFILE
CONE MORAINE
SEE INSET MAP
GRINNELL GLACIER
GRINNELL NUNATAK
STREAM
RIDGE
TO S-2
110°32' 110°34' 110°36' 110°38' 110°40' 110°42' 110°44' 110°46'
66°13' 66°14' 66°15' 66°16' 66°17' 66°18' S